JUN 7 1923

PRINTED ON THIN PAPER FOR FOREIGN CIRCULATION.

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

VOL. CXV.—No. 2995.] *LONDON: FRIDAY, MAY 25, 1923.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 3d.

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See Advertisement, pages 24 and 25, last week.
PATENT WATER-TUBE BOILERS, AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

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Three 60 inch Water-driven Hydro EXTRACTORS by Watson, Laidlaw & Co., Ltd.; new condition.
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For Sale, Selections from
Stock at Reduced Prices.
Numerous AIR COMPRESSORS, Belt and Steam driven, from 10 ft. up to 2178 cubic feet.
MACHINE TOOLS of every Description. Shipyard Plant and Equipment a Speciality.
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PATENT BOILERS. *See page 80, May 18.* 1283
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in Brass and Copper.
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Kingston Metal Works,
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STATIONARY, STEAM AND MARINE ENGINEERS,
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BRADFORD.
HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896

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of all types and sizes.
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SHALLOW DRAFT VESSELS. 818

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See page 17, May 18. 1134

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TRANSPORTER CO., LTD.,
CONTRACTING ENGINEERS.
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Phone—Holb. 541. Tele.—Andrubo, Holb., London.
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See's Hydro-Pneumatic **Ash Ejector.**
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

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Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 617
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HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 67.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM and GAS KETTLES, Merrill's Patent TWIN STRAINERS for Pump Suctions, SYPHONIA STEAM TRAPS, REDUCING VALVES High-class GUNMETAL STEAM FITTINGS. WATER SOFTENING and FILTERING. 5733
Row's PATENTS.

IRON & STEEL
Tubes AND Fittings
AND
Steel Plates.
STEWARTS AND LLOYDS, Ltd.
GLASGOW - BIRMINGHAM - LONDON.
See Advertisement Page 98. 1111

Drag Line Excavator.
Has moved 2,000 cube yards in one day. May be seen at Frodsham, near Chester. Reach 77 ft.; lift four to five tons; speed of working, one to three cuts a minute.
HARRY FAIRCLOUGH, Contractor, WARRINGTON. 1107

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Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c., &c. 846

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of every description.
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DAVID BROWN & SONS (Hudd.) LTD.,
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THOMAS HUNT & SONS,
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Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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LIMITED.
See Advertisement page 60, May 18. 2402

New Tool Steel, &c., For Sale
at considerably under Makers' prices. Enquiries solicited from Users and Stockholders. Complete detailed specification on application comprising roughly:—

CAST STEEL FOR TOOLS	435 tons.
SPECIAL CAST STEEL FOR TOOLS	220 tons.
SHEAR TEMPER STEEL	50 tons.
DOUBLE SHEAR STEEL	40 tons.
NICKEL STEEL SHEETS	75 tons.

GEO. COHEN SONS & CO.,
600, Commercial Road, London, E. 14.
A 491

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FELLOWS BROS, LTD., 2158
CRADLEY HEATH, STAFFS.

Railway Switches and Crossings.
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GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED
Duckham's Patent Suspended
WEIGHING MACHINES—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes. Grain Elevators, &c. See Illus. Advt. last week, page 15. 991

WAYGOOD-OTIS LIFTS 1415
54 & 55, FETTER LANE, LONDON, E.C. 4,
62 & 63, LIONEL STREET, BIRMINGHAM,
and Principal Provincial Cities and Abroad.

Petter Oil Engines.
For Paraffin and Crude Oil
Sizes 1½ B.HP. and upwards
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Vickers-Petters, Ltd., Ipswich
See advertisement alternate weeks. 2530

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Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
999
See half-page Advertisement, page 66, May 11.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

Chief Engineer: C. E. STROMEYER, M.I.C.E.

Founded 1854 by Sir WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

The Institute of Physics.

EXAMINATION FOR THE ASSOCIATESHIP, 1923.

Notice is Hereby Given that the Institute will hold its EXAMINATION OF CANDIDATES for the Associateship in London at the latter end of September, 1923. Applications for entry must be received before June 30th.

Forms of Application and copies of the papers set in 1922 can be obtained from the Secretary.

Regulations for admission into the Institute without examination will also be sent on application.

By Order of the Board,
F. S. SPIERS,
Secretary.

10, Essex Street,
London, W.C.2. A 597

Messrs. George Cradock

& CO., LTD., Steel Wire and Wire Rope Works, Wakefield, beg to give notice that Mr. HORACE R. SMITH, formerly their Representative in the Midlands and South Wales, ceased to represent them as and from 16th May, last, and that he is not authorised to act on their behalf in any capacity whatsoever. A 636

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and ALL ENGINEERING EXAMINATIONS personally conducted by Mr TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 5/11, TRAFFORD CHAMBERS, 55, SOUTH JOHN STREET, LIVERPOOL. 1296

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

TENDERS.

PORT OF BRISTOL.

RECONSTRUCTION OF TRANSIT SHED "U," BRISTOL.

The Docks Committee invite

Tenders for the Reconstruction

(mainly in ferro-concrete) of the DOUBLE FLOOR TRANSIT SHED known as Shed "U," situate on Canon's Road, Bristol.

On and after Monday, the 28th day of May, 1923, a copy of the Form of Tender, General Conditions, Specification, Schedule of Prices, and a Copy of the Contract Drawings can be obtained from the undersigned on production of a receipt showing that a deposit of £5 has been paid to the General Manager and Secretary of the Docks Committee, to whom all cheques must be made payable. The deposit of £5 will be returned hereafter to all *bona fide* Tenderers.

Tenders must be enclosed in a sealed envelope, endorsed "Tender for Reconstruction of Shed 'U,' Bristol," and addressed to the General Manager and Secretary of the Docks Committee, 19, Queen Square, Bristol, and must be delivered to him, accompanied by all the prescribed documents and drawings, before Ten a.m. on Monday, the 18th day of June, 1923.

The Docks Committee do not bind themselves to accept the lowest or any Tender.

THOMAS A. PHACE,
Engineer,
Port of Bristol.

Chief Engineer's Office,
Avonmouth Docks,
18th May, 1923. A 561

DEPARTMENT OF PUBLIC WORKS,
Sydney, 31st January, 1923.

SYDNEY HARBOUR BRIDGE TENDERS—EXTENSION OF TIMB.

Tenders are Invited by

the Government of New South Wales for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF A CANTILEVER BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1600 feet in the clear, centre to centre of main piers, and a length of main bridge 3500 feet centre to centre of anchor piers. The total length of main bridge and approach spans included in tender is 3810 feet; also an ALTERNATIVE TENDER for the CONSTRUCTION OF THE SUPERSTRUCTURE AND SUBSTRUCTURE OF AN ARCH BRIDGE ACROSS SYDNEY HARBOUR FROM DAWES POINT TO MILSON'S POINT, embracing a main span of 1650 feet in the clear centre to centre of bearings. The total length of main bridge and approach spans included in tender is 3770 feet. Either bridge is to provide for four lines of railway, six lines of vehicular traffic, and footway accommodation.

Copies of Specification, including Plans, Technical Information, General Conditions, and Tender Forms, may be obtained by *bona fide* tenderers on application to the Under Secretary for Public Works, Sydney, or to the Agent-General for New South Wales, Australia House, The Strand, London; the Minister of Railways and Canals, Ottawa; The Australian Trade Commissioner in the United States, New York; or the Bureau of Foreign and Domestic Commerce, Washington, D.C., United States.

Tenders, the time for which has been extended, must reach the Under Secretary for Public Works Sydney, New South Wales, not later than 30th November, 1923.

R. T. BALL, A 59
Minister for Public Works and Railways.

ADMINISTRATIVE COUNTY OF LONDON.

REPAIRS TO PAVEMENTS, BLACKWALL AND ROTHERHITHE TUNNELS.

Tenders are Invited for

REPAIRS to the PAVEMENTS of BLACKWALL and ROTHERHITHE TUNNELS.

The Specification, Form of Tender, etc., may be obtained on application to the Chief Engineer of the Council, at the Old County Hall, Spring Gardens, S.W. 1, upon payment of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract documents may be inspected before payment of the fee.

No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.E. 1, after Four p.m. on Monday, 11th June, 1923, will be considered. A 622

JAMES BIRD,
Clerk of the London County Council.

CITY OF LEEDS.

ELECTRICITY DEPARTMENT.

TURBINES, ALTERNATORS and CONDENSING PLANT AUXILIARIES FOR SALE By Private Treaty.

Offers are Invited for the

following PLANT, discarded to make room for larger sets:—

TWO 4000 B.HP. HORIZONTAL REACTION TYPE STEAM TURBINES.
TWO MOTOR DRIVEN, THREE THROW, AIR PUMPS.
TWO MOTOR DRIVEN CENTRIFUGAL PUMPS.
TWO 3000 KILOWATT TWO-PHASE ALTERNATORS AND EXCITERS.

With the exception of one Alternator, which requires repairs to the windings, the plant is in good working order, and it can be inspected by appointment.

Offers will be considered for the whole or any part of the plant. The Specification, &c., may be obtained from the undersigned. The Corporation do not bind themselves to accept any Offer.

Offers are to be addressed to "The Manager, Electricity Department, 1, Whitehall Road, Leeds," C. NELSON HEFFORD,
Manager.

1, Whitehall Road,
Leeds, 22nd May, 1923. A 592

ABERDEEN CORPORATION WATER WORKS.

EXTENSIONS 1920.

CONTRACT No. 10—NEW AQUEDUCT.

The Town Council of Aberdeen are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the MANUFACTURE and DELIVERY of about 3 miles of 4 feet diameter PIPES and SPECIALS of the following alternative types, viz:—

(A) Cast Iron.
(B) Mild Steel (Lapwelded).

The Drawings may be inspected and Specification, Schedule of Quantities and Form of Tender obtained, on and after 30th May, 1923, on application at the Water Engineer's Office, 41½, Union Street, Aberdeen. Early application is desirable and no specification will be given out after 8th June.

For each Specification of each type a deposit of Five Pounds sterling will be required, which sum will, after a Tender has been accepted, be returned to the tenderer, provided that he shall have sent in a *bona fide* Tender, based on the Drawings, Specification and Schedule of Quantities provided, with the Schedule of Quantities fully priced out in detail, and shall not have withdrawn the same.

Tenders on the Forms prescribed and enclosed in securely sealed envelopes, endorsed "Tender for New Aqueduct Piping" are to be addressed to the undersigned. No Tender delivered after Five p.m. on the 22nd June, 1923, will be considered.

The Town Council do not bind themselves to accept the lowest or any Tender.

GEORGE MITCHELL, M.Inst.C.E., F.G.S.
Water Engineer.

Water Engineer's Office,
41½, Union Street, Aberdeen.
21st May, 1923. A 611

ABERDEEN CORPORATION WATER WORKS.

EXTENSIONS 1920.

CONTRACT No. 11.—NEW AQUEDUCT.

The Town Council of Aberdeen are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the TRANSPORTING, LAYING and JOINTING of about Three Miles of 4-ft. PIPING, and ANCILLARY WORKS between CULTER and WEST CULTS.

The Drawings may be inspected, and Specification, Schedule of Quantities, and Form of Tender obtained, on and after 30th May, 1923, on application at the Water Engineer's Office, 41½, Union Street, Aberdeen. Early application is desirable, and no Specification will be given out after 8th June.

For each Specification a deposit of Five Pounds Sterling will be required, which sum will, after a Tender has been accepted, be returned to the Tenderer, provided that he shall have sent in a *bona fide* Tender, based on the Drawings, Specification and Schedule of Quantities provided, with the Schedule of Quantities fully priced out in detail, and shall not have withdrawn the same.

Tenders, on the Forms prescribed, and enclosed in securely sealed envelopes, endorsed "Tender for Aqueduct Pipelaying," are to be addressed to the undersigned. No Tender delivered after Five p.m. on 22nd June, 1923, will be considered.

The Town Council do not bind themselves to accept the lowest or any Tender.

No person should Tender unless thoroughly experienced in the actual construction of extensive public works.

GEORGE MITCHELL, M.Inst.C.E., F.G.S.,
Water Engineer.

Water Engineer's Office,
41½, Union Street, Aberdeen.
21st May, 1923. A 612

COUNTY BOROUGH OF PORTSMOUTH.

Tenders are Invited for:—

(A) The REMOVAL of a 60 ft. ELECTRICALLY OPERATED BASCULE BRIDGE: and/or
(B) The PURCHASE and REMOVAL of same.

For further particulars and illustration of Bridge, see page 95. A 625

Town Hall, Portsmouth. F. J. SPARKS,
17th May, 1923. Town Clerk.

B. B. & C. I. RAILWAY COMPANY.

The Directors are prepared to receive up to Noon, on Wednesday, 13th June,

Tenders for the Supply of:—

(1) STEEL MATERIAL
(2) COPPER FIREBOX PLATES
(3) STEEL BOILER TUBES.

Tenders must be made on forms, copies of which, with Specification, can be obtained at these Offices on payment of 10s. each (which will not be returned).

The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG,
Secretary.

Offices: 91, Petty France,
Westminster,
S.W.1.
17th May, 1923. A 596

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

	Fee for Specification.
Four-Wheel Covered and Open Wagons (with rolled steel disc Wheels and Axles, Axleboxes, and Laminated and Helical Springs).	£1.

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Four-Wheel Covered and Open Wagons," not later than Eleven o'clock a.m., on Tuesday, the 12th June, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 23rd May, 1923. A 641

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely:—

		Fee for Specification.
1.	Solid Drawn Steel Boiler Tubes ...	10/-
2.	Canvases	5/-
3.	Paints, Drysalteries, &c.	10/-
4.	Steel Work for Bridges	5/-
5.	Iron or Steel Screws	5/-
6.	Wood Handles	2/6
7.	Leather Belting, &c.	10/-
8.	Galvanized Stamped Steel Mortar Pans	5/-
9.	Spring Steel	2/6
10.	Canvas Hose Pipes	10/-
11.	Galvanized Wrought Iron Water Tubes, &c.	10/-
12.	Stationery, &c.	5/-

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Solid Drawn Steel Boiler Tubes," or, as the case may be, not later than Eleven o'clock a.m., on Tuesday, 5th June, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 23rd May, 1923. A 640

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme.

Copies of Tender Form and Specification will be available upon application to:—

AGENT-GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C. 2.

SPECIFICATION No. 20/77.
ALUMINIUM STEEL CORED CABLE
0.0707 SQ. IN.

CHARGE:—£2 for the first three copies of Tender Form, Conditions of Contract, Specification complete. These charges will be returned on receipt of a *bona fide* Tender. A fourth copy and any further copies will be supplied for the sum of 10s. each.

PRELIMINARY DEPOSIT:—A preliminary deposit of £100 is to be lodged with the Tender.

The Specification may be inspected at the above-mentioned office.

The Commission does not bind itself to accept the lowest or any Tender.

Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne not later than Five p.m., 31st August, 1923.

R. LIDDELOW,
Secretary,
State Electricity Commission of Victoria,
Melbourne, Victoria,
Australia. A 629

ADMINISTRATIVE COUNTY OF LONDON.

SALE OF ELECTRICAL POWER STATION MACHINERY.

The London County Council invites

Tenders for the Purchase and

REMOVAL of GENERATING SETS, BOILERS, COAL CONVEYOR, COOLING TOWER, FEED PUMPS, and WATER SOFTENING PLANT.

The Plant may be inspected at the London United Electric Tramways Power Station, 74, High Road, Chiswick, between the hours of Ten a.m. and Four p.m. on any weekday, except Saturday, from 4th to 11th June, 1923, both dates inclusive, by appointment with a representative of the Council.

Particulars and Form of Tender may be obtained from the General Manager, London County Council Tramways, Victoria Embankment, W.C. 2.

Tenders must be delivered to the Clerk of the Council at the County Hall, Westminster Bridge, S.E. 1, not later than Twelve noon on Tuesday, 12th June, 1923. No Tender received after that time will be considered.

The Council does not bind itself to accept the highest or any Tender.

JAMES BIRD,
Clerk of the London County Council.
A 649

PORT OF BRISTOL.

NEW ELECTRIC CRANES, BRISTOL DOCKS.

The Docks Committee are prepared to receive

Tenders for the Construction

of TWO 2-ton MOVABLE, ELECTRIC, JIB CRANES, and the ERECTION of the SAME on the Roofs of Sheds "Y" and "Z," Canon's Marsh, Bristol Docks.

On and after Thursday, the 31st day of May, 1923, copies of the General Conditions, Specification, Schedule of Prices, and Contract Drawing can be obtained from the undersigned on production of a receipt shewing that a deposit of £3 has been paid to the Bristol Docks Committee, 19, Queen Square, Bristol, to whom all cheques must be made payable. The deposit of £3 will be returned hereafter to all *bona fide* Tenderers.

Tenders must be enclosed in a sealed envelope endorsed "Tender for Two Electric Cranes" and addressed to the General Manager and Secretary of the Docks Committee, 19, Queen Square, Bristol, and must be delivered to him accompanied by all the prescribed documents and drawings before ten a.m. on Monday, the 2nd July, 1923.

The Docks Committee do not bind themselves to accept the lowest or any Tender.

THOMAS A. PHACE,
Engineer,
Port of Bristol.

Chief Engineer's Office,
Avonmouth Docks,
23rd May, 1923. A 644

APPOINTMENTS OPEN.

THE UNIVERSITY OF SHEFFIELD.

PROFESSORSHIP OF MECHANICAL ENGINEERING.

The Council of the University invite

Applications for the above

POSITION, shortly to become vacant.

Applications should be received by the undersigned, from whom further particulars may be obtained, by the 12th June.

W. M. GIBBONS, Registrar. A 58

UNIVERSITY OF BIRMINGHAM.

JAMES WATT RESEARCH FELLOWSHIP.

The Council invites

Applications for the James

WATT RESEARCH FELLOWSHIP in the Thermo-Dynamics of Internal Combustion Engines. Candidates should hold an Honours Degree in Engineering of a British University, and have had some experience in Research. The Fellowship has at present an annual value of £220, and is renewable. Applications should be sent in not later than 31st of May, 1923.

Further particulars may be obtained from the Dean of the Faculty of Science, The University, Edgbaston, Birmingham.

GEO. H. MORLEY,
Secretary.
A 66

CITY OF CARDIFF EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

Principal: CHARLES COLES, B.Sc. (Lond.).

The Services of an Assistant

INSTRUCTOR with good qualifications in Naval Architecture, Experimental Science and Mathematics are REQUIRED in the Marine Technical Department, which includes Marine Engineering and Navigation (B. o. T. Examinations). Practical Shipyard experience is desirable.

Commencing salary £300 per annum, subject to the Regulations of the Committee re percentage deduction.

Applications on foolscap paper, stating age, full qualifications, teaching and other experience, and giving copies of not more than three recent testimonials, should reach the Principal (from whom further particulars may be obtained) not later than 30th May.

The selected candidate, before being appointed, will be required to submit himself for examination by the Authority's Medical Examiner at Cardiff.

JOHN J. JACKSON,
Director of Education, City Hall, Cardiff.
15th May, 1923. A

Managing Director for Large

Shipbuilding, Engineering and Repairing Yard; good position for experienced man: financial interest not required.—Address, stating experience, A 478, Offices of ENGINEERING.

COALDUST EXPLOSION TESTS IN THE BRUCETON EXPERIMENTAL MINE.

THE experimental mine near Bruceton, Pennsylvania, may truly be said to owe its foundations to the sequence of terrible mine explosions, occurring in 1906 at Courrières, where 1,100 lives were lost, and in December, 1907, at Monongah, Western Virginia, and at Darr, Pennsylvania, where 361 and 339 men were killed. By July, 1908, Congress had granted funds for investigating the causes of mine explosions, placing the work in charge of the late Dr. Joseph Holmes, under the United States Geological Survey. When coaldust work was properly started in the new experimental mine near Bruceton, in 1911, two terrific explosions, suspending operations in that mine for nearly a year, helped to overcome the apathy of the general public and of many miners still unconvinced of the dangers of dust in the absence of inflammable gas. There was no further difficulty in obtaining some 30,000 dols. annually for the continuation of the work, on which 240,000 dols. were spent up to 1918.

Yet scientists and miners had urged for almost a century that the increasing violence of mine explosions was more due to the accumulation of coal-dust in the larger and more intensely-worked mines than to the dreaded firedamp. In the 10 years 1901 to 1910 there were recorded in the United States 106 gas and dust explosions, each killing five men or more, in bituminous or sub-bituminous mines. The figures did not include anthracite colliery explosions, then recognised as more local owing to the practical absence of coal dust. But those 106 explosions took 3,296 lives, and in the ten years following 1911 to 1920, 75 explosions killed 2,057 men, a reduction of 1,239 in the number of victims, although the number of miners and the output had risen by nearly one-half. In the last three years of the latter period, moreover, the number of victims fell to 41, 87 and 47; the researches conducted in America and elsewhere were evidently bearing fruit.

Before Holmes had decided upon the Bruceton site, he had visited the experimental galleries at Gelsenkirchen, near Essen, at Frameries, Belgium, and the more recent galleries at Altofts and at Liévin, France. The coal-dust problem was being studied in these places; but they were all surface galleries, and the only underground gallery in the Segen-Gottes Schacht, near Brünn, Moravia, had hardly any means for investigating the propagation of coal-dust explosions, apart from coal-dust ignition. Holmes himself first tested safety explosives in an experimental steel gallery, 100 ft. long, erected at Pittsburgh. Not being able to find a suitable mine for underground research, he made horizontal entries into the outcrop of a coal bed at the foot of a hill near Bruceton. Meanwhile, the Bureau of Mines, created in 1910, had taken up this investigation, and when Holmes died, the work was placed in charge of George S. Rice, assisted by L. M. Jones, W. L. Egy and H. P. Greenwalt. The successive bulletins drawn up by these investigators, informed the miners of progress made and of precautionary measures to be adopted. But the outbreak of the war delayed the issue of a comprehensive account which, as recently published (Bulletin 167, 639 pages; Washington: Government Printing Office; price 1 dol.) under the title, "Coal-Dust Explosion Tests in the Experimental Mine, 1913 to 1918, Inclusive," deals essentially with the period named, but refers also to more recent results.

The mine entries mentioned consist of two parallel horizontal main drifts, 1,300 ft. long, 9 ft. wide, 6½ ft. high and 41 ft. apart, crossed at distances of 800 ft. and 950 ft. from the mouth, at right angles, by butt entries, from which a series of side chambers branch off, and by shorter side branches leading to stations; a third gallery joins the left main at an acute angle about 150 ft. from the mouth. The two mains are connected by curved or straight "cut-throughs," which are closed by 18-in. reinforced concrete stoppings; these stoppings, as well as the heavy stone pillars at the entrances, have withstood the explosions, except the one stopping at 650 ft. from the mouth, which was cracked and finally blown out, and was then replaced by 2 ft. of concrete. The coal seam, about 5 ft. thick, is overlain by clay and layers of coal and slate. The coal makes an excellent roof without timbering. There was never any appreciable liberation of methane, and the galleries were practically dry, especially in the winter, the chief experimental season. To keep the galleries dust free, except where dust is spread, the floor was concreted, and the walls were lined with cement-sand with the aid of a gun. The lateral openings are closed by flush steel doors.

Among the manifold instruments used are chronographs, various pressure gauges—explosion-temperature measurements failed—automatic gas samplers; tinfoil indicators, tufts of gun cotton and safety matches to be fused or burnt by the flame; photographic recorders and air direction vanes so arranged that the deflections, first to the one side and then to the other, will chronographically be recorded. The explosions are generally initiated by discharging a cannon, charged with 4 lb. of black powder and so mounted at the far end of the main entry, in front of the coal face, that the discharge and the flame, 20 ft. long, stir up coal dust from shelves near the gun. The shock-wave of the gun shot seemed to start at the acoustical wave speed of 1,100 ft. per second, but the speed increased to 1,500 ft.; and that speed was independent of the deflections of the wave by the cross-cuts. The pressure of that wave rose in 0·2 second to 610 ft. per square inch, then falling off rapidly. The dust-explosion wave took a second to travel the first 100 ft., but gained speed rapidly to 2,000 ft. and more; the maximum flame speed observed was 6,000 ft. per second. The pressure of this explosion wave rose from 15 lb. per square inch at 150 ft. from the origin to 63 lb. and 119 lb. at 350 ft. and 750 ft., and reached in one case probably 145 lb. per square inch. Two factors have to be distinguished in the air velocity. There is wave motion and also actual transference of gas; the latter may be stopped or reversed by obstacles, but attempts to measure this transference speed by means of a rubber disc sliding with its tubular axis on a wire were unsatisfactory. There is, of course, also a backward retonation or reflected wave, which often piled up the *debris* near the origin of the explosion and carried one laden coal truck 147 ft. inward. The ventilating current and its direction had no influence on the explosion wave, and the inrush of air (described by some experimenters) to meet the advancing wave, was not observed.

In some experiments the gun was mounted near the mouth of the entry. Within 100 ft. of the entry it would not start an explosion, whether fired inward or outward; but it would at 168 ft., especially if pointing inward and with dense dust clouds. Cross-fires by two guns were also tried. The admixture of a few per cent. of methane made little difference on the explosibility limits of the coal dust, 1 per cent. of methane requiring 5 per cent. more shale dust for neutralisation than coal dust alone. In a measure fine coal dust is more explosive than most gases, that is with respect to concentration limits. Whilst methane-air mixture will only propagate an explosion within the range 4 per cent. to 12 per cent. of methane, 0·05 ounces of coal dust per cubic foot of air (50 grammes per cubic metre), an almost invisible turbidity, may set up an explosion, and an enormous excess of coal dust would not prevent it, though it would make the propagation slow, and the pointed flame would not spread sideways, thus lessening fire risks.

The pulverised coal dust used was finer than ordinary coal dust and, it would appear that the inflammability much increases with the percentage of the finest dust passing through 200 mesh. But friable coal gives off such fine dust in the mines, and this dust settles on the walls, timber and roof—deposits which are often disregarded in discussion of this problem—while the coarser mine-road dust will not contain more than 20 per cent. of the fine particles. The presence of moisture and of other inert matter will decrease the inflammability, which 75 per cent. of inert matter would stop; in how far volatile constituents in the coal raise the inflammability is still controversial. Liquid water will stop an explosion. But a moisture-saturated atmosphere, from which coal dust does not readily take up enough water, is insufficient, and the miners cannot work in steam clouds. To be safe the coal dust should contain at least 30 per cent. of water or be wet; the wetting has to be renewed daily, and sprinkling with powdered or dissolved calcium chloride was found inefficient. That is not surprising. Calcium chloride absorbs moisture, and each particle turns into a wet globule which draws the moisture out of the coal, instead of diffusing it, unless the dust is well stirred and mixed. The wetting of coal dust, it was observed, is much facilitated by the presence of stone dust, whilst layers of dry coal dust, 1 in. thick, were found floating on the water pools of a mine a year after it had been abandoned.

Dustless zones, even of 1,000 ft. length, swept of all coal dust, proved of little use in stopping an explosion wave, these various observations pointed to the good services of rock dust, shale or limestone being used. Dust of about 20 mesh containing 30 per cent. of fine dust of 100 mesh to 200 mesh, seemed to answer best; but a good deal of rock dust, as much or as twice as much as coal dust, may be required. "Mantles" of rock dust were first produced by distributing the shale on the top of the coal or by throwing it against the walls and roof on which the fine particles stuck like paint; sometimes alternating layers of coal and rock were spread. It was found, however, that the explosion would itself produce the necessary mixing. A continuous dust zone of 400 ft. length (shale dust, 700 ft. for limestone) would stop an explosion created in a coal-dust zone 300 ft. long; but intermittent dust zones were not reliable, and attention was thus concentrated on dust troughs and shelves which, upset by the explosion, would give efficient dust clouds. Such arrangements are far less troublesome than the creation of continuous dust, zones, which have constantly to be replenished as more dust collects, and the shelves and troughs, attached to the walls and roof lengthways or crossways, can, moreover, be combined with barriers erected to stop or to break the force of the explosion.

We have mentioned already that all the cut-through stoppings, except one, withstood the explosions, although these were often of quite exceptional violence. Of 207 barriers tested, 173 stopped the flames, and of the rest, 15 were not reached by them. In shape and construction the doors and barriers, themselves sometimes consisting of sets of troughs or boxes, V-shaped or square, varied very much; the Bulletin gives illustrations. In one type of barrier the boxes were attached to the ceiling by levers, and they sent feelers, hinged planks, 100 ft. in length, backward to the source (the coal face); that structure had to be modified as it endangered the workers. Not all the devices answered, and weak barriers were simply swept away without checking the explosion violence. But subsequent experiments have confirmed the efficiency of dust clouds and of strong barriers, and further information on the best methods of rock dusting will be welcome.

INTERNAL-COMBUSTION ENGINE CAMS.

By B. B. Low, B.A.(Cantab.).

THIS paper gives a mathematical analysis of cams most generally used in internal-combustion engines and also considers definite examples showing the relative merits as regards average lift, spring strength, noise, &c., of different types. Owing to the inherent inaccuracies of graphical methods the mathematical analysis is to be preferred; also it is undoubtedly quicker to substitute numerical values in a formula than to undertake a comparatively long graphical construction.

Four types of cams are discussed—concave, straight and convex cams with roller followers, and a convex cam with a flat-footed follower (Figs. 1 to 4). The cam is defined as concave, straight to convex according as A B and A′ B′ are concave, straight or convex.

All the curves used in the construction of the cams are circular arcs. From A to B the follower is accelerated by the cam, and from B to D is retarded by the valve spring. From D to D′ the follower is stationary, but the points D and D′ may coincide, in which case there is no dwell when the valve is fully open. At D′ the direction of motion of the

follower is reversed. From D′ to B′ the follower is accelerated by the valve-spring, and from B′ to A′ it is retarded by the cam. As each cam is symmetrical, it will be sufficient to consider the motion of the follower from the beginning of the lift to full lift or to the point of mid-dwell. In what follows, A B is spoken of as the "first curve" and B D as the "second curve."

The strength of the valve-spring will be proportional to the maximum retardation on B D, the second curve, or to the maximum acceleration on D′ B′ which has the same numerical value.

The clearance between the tappet and valve when the engine is running has been taken as 0·2 mm. in each case. The "clearance angle" or angle through which the cam turns before the tappet strikes the valve-stem is different for different-shaped cams, and it has been calculated for all the cams considered

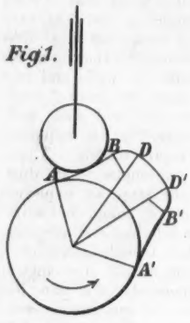


Fig. 1.

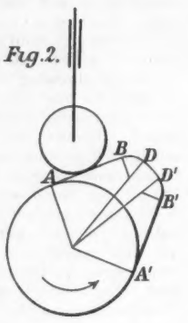


Fig. 2.

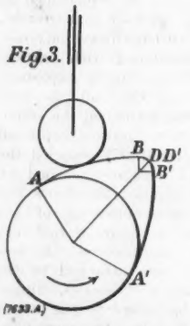


Fig. 3.

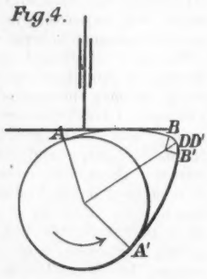


Fig. 4.

by equating the lift expressions to 0·2 mm. For a fair comparison, the total angle through which the various cams move, whilst the valves are in operation, must be the same and this has been taken as 111 deg. or 55° 30′ for the half angle.

The speed of the crankshaft has been assumed as 1,400 r.p.m., hence for the camshaft

$$\frac{d\theta}{dt} = \frac{1400}{2 \times 60} \times 2\pi$$

radians per second.

Concave Cam (Fig. 5).

First Curve.—

Let tappet lift = h. Then valve lift = h − clearance.
Let $(r_1 + r_3) = a$ and $(r_3 - r_2) = b$.

Referring to Fig. 5—

$$b \sin \phi = a \sin \theta$$
$$\sin \phi = \frac{a}{b} \sin \theta$$

Therefore

$$\cos \phi = \frac{1}{b} \{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}$$

Lift

$$h = a \cos \theta - b \cos \phi - (r_1 + r_2)$$
$$= a \cos \theta - \{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}} - (r_1 + r_2) \quad . \quad (1)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt}\left[-a \sin \theta + \frac{a^2 \sin 2\theta}{2\{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}} \right] \quad . \quad (2)$$

Acceleration

$$\frac{d^2h}{dt^2} = \left(\frac{d\theta}{dt}\right)^2 \left[-a \cos \theta + \frac{a^2 \cos 2\theta}{\{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}} + \frac{a^4 \sin^2 2\theta}{4\{b^2 - a^2 \sin^2 \theta\}^{\frac{3}{2}}} \right] = \left(\frac{d\theta}{dt}\right)^2 \left[-a \cos \theta + \frac{a^2\{a^2 \sin^4 \theta + b^2 \cos 2\theta\}}{\{b^2 - a^2 \sin^2 \theta\}^{\frac{3}{2}}} \right] \quad . \quad . \quad . \quad (3)$$

These three equations hold from $\theta = 0$ to $\theta = \theta_1$.

Second Curve.—

Let $(r_5 - r_4) = d$ and $(r_2 + r_4) = f$

Referring to Fig. 5,

$$\sin \psi = d \sin (\theta_2 - \theta)$$
$$\sin \psi = \frac{d}{f} \sin (\theta_2 - \theta).$$

Therefore

$$\cos \psi = \frac{1}{f}\left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}$$

Lift

$$h = d \cos (\theta_2 - \theta) + f \cos \psi - (r_1 + r_2)$$
$$= d \cos (\theta_2 - \theta) + \left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}^{\frac{1}{2}} - (r_1 + r_2) \quad . \quad (4)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt}\left[d \sin (\theta_2 - \theta) + \frac{d^2 \sin 2(\theta_2 - \theta)}{2\left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}^{\frac{1}{2}}} \right] \quad (5)$$

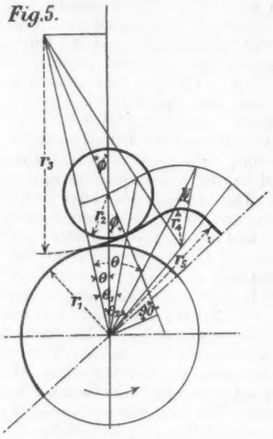


Fig. 5.

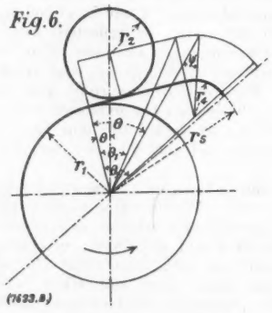


Fig. 6.

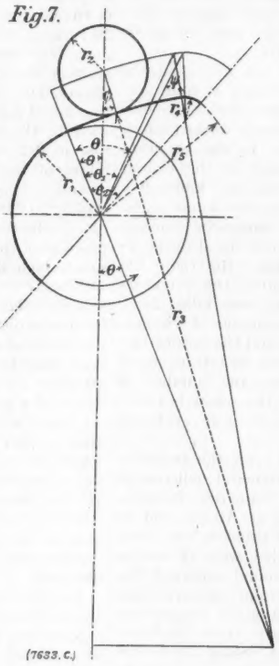


Fig. 7.

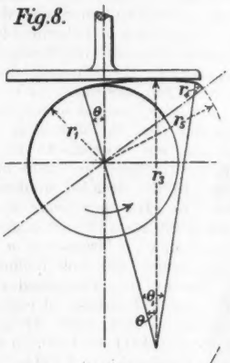


Fig. 8.

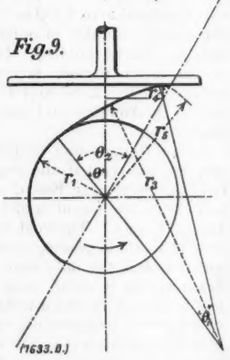


Fig. 9.

Acceleration

$$\frac{d^2h}{dt^2} = \left(\frac{d\theta}{dt}\right)^2 \left[-d \cos (\theta_2 - \theta) - \frac{d^2 \cos 2(\theta_2 - \theta)}{\left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}^{\frac{1}{2}}} - \frac{d^4 \sin^2 2(\theta_2 - \theta)}{4\left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}^{\frac{3}{2}}} \right] = -\left(\frac{d\theta}{dt}\right)^2 \left[d \cos (\theta_2 - \theta) + \frac{d^2\{d^2 \sin^4 (\theta_2 - \theta) + f^2 \cos 2(\theta_2 - \theta)\}}{\left\{ f^2 - d^2 \sin^2 (\theta_2 - \theta) \right\}^{\frac{3}{2}}} \right] \quad . \quad . \quad (6)$$

These three equations hold from $\theta = \theta_1$ to $\theta = \theta_2$.

Dimensions.—

Assume

$r_1 = 14 \cdot 75$ mm., $r_2 = 7 \cdot 5$ mm., $r_3 = 35 \cdot 0$ mm., $r_4 = 6 \cdot 0$ mm., $r_5 = 24 \cdot 5$ mm.

Hence

$$a = (r_1 + r_3) = 49 \cdot 75 \text{ mm.}$$
$$b = (r_3 - r_2) = 27 \cdot 5 \text{ mm.}$$
$$d = (r_5 - r_4) = 18 \cdot 5 \text{ mm.}$$
$$f = (r_2 + r_4) = 13 \cdot 5 \text{ mm.}$$

Putting $h = 0 \cdot 2$ in equation (1) gives the clearance angle = 5° 41′. Therefore half the cam angle = 5° 41′ + 55° 30′ = 61° 11′. By calculation θ_1 = 22° 6′ and θ_2 = 51° 53′. If the figure is drawn to a fairly large scale θ_1 and θ_2 can be measured with sufficient accuracy.

Inserting the appropriate data in equations (1) to (6), and substituting different values of θ, gives the lift, velocity and acceleration curves shown in Figs. 10 to 12.

The total angle turned through by the cam whilst the valve is fully open is equal to—

$$2(61° 11′ - 51° 53′) = 18° 36′.$$

Straight Cam (Fig. 6).

First Curve.—

Let tappet lift = h.
Then valve lift = h − clearance.

Lift

$$h = \frac{r_1 + r_2}{\cos \theta} - (r_1 + r_2)$$
$$= (r_1 + r_2)\left(\frac{1}{\cos \theta} - 1\right) \quad . \quad . \quad (7)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt}(r_1 + r_2)\frac{\tan \theta}{\cos \theta} \quad . \quad . \quad (8)$$

Acceleration

$$\frac{d^2h}{dt^2} = \left(\frac{d\theta}{dt}\right)^2 (r_1 + r_2)\left(\frac{1 + 2\tan^2 \theta}{\cos \theta}\right) \quad . \quad (9)$$

These three equations hold from $\theta = 0$ to $\theta = \theta_1$.

Second Curve.—This curve is the same as the second curve of the concave cam, hence equations (4), (5) and (6) will give lift, velocity and acceleration respectively, for the second curve of the straight cam. The limits are $\theta = \theta_1$ and $\theta = \theta_2$.

Dimensions.—In fixing the dimensions for the straight cam it is necessary to aim at making the conditions as nearly as possible, the same as in the previous case. The maximum lift must be the same, so, if r_1 and r_2 are unaltered, then r_5 must also be unaltered. r_4 might be slightly increased without altering the maximum lift, but even when r_4 remains unaltered θ_2 for the straight cam is considerably greater than θ_2 for the concave cam, so that the angle turned through by the straight cam whilst the valve is fully open, is smaller than the corresponding angle turned through by the concave cam and increasing r_4 would reduce this angle still more. Therefore r_4 will be kept unchanged.

Hence the dimensions are:

$r_1 = 14 \cdot 75$ mm., $r_2 = 7 \cdot 5$ mm., $r_4 = 6$ mm., $r_5 = 24 \cdot 5$ mm.

$$d = (r_5 - r_4) = 18 \cdot 5 \text{ mm.}$$
$$f = (r_2 + r_4) = 13 \cdot 5 \text{ mm.}$$

Putting $h = 0 \cdot 2$ mm. in equation (7) gives the clearance angle = 7° 39′.

Therefore half the cam angle = 7° 39′ + 55° 30′ = 63° 9′.

By calculation, θ_1 = 36° 13′ and θ_2 = 61° 46′.

As before θ_1 and θ_2 may be found by measurement with sufficient accuracy, if the figure be drawn to a large scale.

Inserting the appropriate data in equations (7) to (9) and (4) to (6), and substituting different values of θ gives the lift, velocity and acceleration curves shown in Figs. 10 to 12.

The total angle turned through by the cam whilst the valve is fully open is equal to 2 (63° 9′ − 61° 46′) = 2° 46′.

Convex Cam. (Fig. 7.)

First Curve.—

Let tappet lift = h. Then valve lift = h − clearance.

Let $(r_5 - r_1) = a$ and $(r_3 + r_2) = b$.

Referring to Fig. 7—

$$b \sin \phi = a \sin \theta$$

$$\sin \phi = \frac{a}{b} \sin \theta$$

Therefore

$$\cos \phi = \frac{1}{b} \{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}$$

Lift

$$h = b \cos \phi - a \cos \theta - (r_1 + r_2)$$
$$= -a \cos \theta + \{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}} - (r_1 + r_2) \quad (10)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt} \left[a \sin \theta - \frac{a^2 \sin 2\theta}{2 \{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}} \right] \quad . \quad (11)$$

Acceleration

$$\frac{d^2h}{dt^2} = \left(\frac{d\theta}{dt}\right)^2 \left[a \cos \theta - \frac{a^2 \cos 2\theta}{\{b^2 - a^2 \sin^2 \theta\}^{\frac{1}{2}}} - \frac{a^4 \sin^2 2\theta}{4 \{b^2 - a^2 \sin^2 \theta\}^{\frac{3}{2}}} \right]$$
$$= \left(\frac{d\theta}{dt}\right)^2 \left[a \cos \theta - \frac{a \{a^2 \sin^4 \theta + b^2 \cos 2\theta\}}{\{b^2 - a^2 \sin^2 \theta\}^3} \right] \quad (12)$$

These three equations hold from $\theta = 0$ to $\theta = \theta$.

It will be noticed that equations (1), (2) and (3) could be employed instead of equations (10), (11) and (12) by treating r_3 as a negative quantity and using negative values where roots are extracted. It was thought advisable, however, for the sake of clearness to make a separate analysis as above.

Second Curve.—The equations of this curve are the same as for the second curve of the concave cam, hence equations (4), (5) and (6) will give lift, velocity and acceleration, respectively, for the second curve of the convex cam. The limits are $\theta = \theta_1$ and $\theta = \theta_2$.

Dimensions.—The radii r_1, r_2, and r_5 are kept the same as before. r_3 should be as small as possible in order to retain the advantages of the convex cam, and r_4 should be as great as possible because it will be found that the strength of the valve spring required increases as r_4 decreases.

Assume a clearance angle and find half the cam angle by adding 55° 30′, then r_3 and r_4 may be found graphically by trial and error for a first approximation. r_3 has been taken as 90 mm. Insert this value of r_3 in the lift equation (10) and put $h = 0{\cdot}2$ mm. This gives the clearance angle as 8° 43′. Hence half the cam angle = 8° 43′ + 55° 30′ = 64° 13′. This angle is marked off and r_4 made as great as possible by trial and error. r_4 has been taken as 3·5 mm.

Hence

$$a = (r_3 - r_1) = 75{\cdot}25 \text{ mm.}$$
$$b = (r_3 + r_2) = 97{\cdot}5 \text{ mm.}$$
$$d = (r_5 - r_4) = 21{\cdot}0 \text{ mm.}$$
$$f = (r_2 + r_4) = 11{\cdot}0 \text{ mm.}$$

If the cam is re-drawn using these dimensions, θ_1 and θ_2 may be measured with sufficient accuracy. By calculation $\theta_1 = 46° 58′$ and $\theta_2 = 64° 8′$.

Inserting the appropriate data in equations (10) to (12) and (4) to (6) and substituting different values of θ gives the lift, velocity and acceleration curves shown in Figs. 10 to 12.

The total angle turned through by the cam whilst the valve is fully open is equal to 2 (64° 13′ − 64° 8′) = 10′ which can be neglected.

Convex Cam with Flat-footed Follower. (Figs. 8 and 9.)

First Curve.—

Let tappet lift = h. Then valve lift = h − clearance.

Referring to Fig. 8—

Lift

$$h = r_3 - (r_3 - r_1) \cos \theta - r_1$$
$$= (r_3 - r_1)(1 - \cos \theta) \quad . \quad . \quad . \quad (13)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt} (r_3 - r_1) \sin \theta \quad . \quad . \quad (14)$$

Acceleration

$$\frac{d^2h}{dt^2} = \left(\frac{d\theta}{dt}\right)^2 (r_3 - r_1) \cos \theta \quad . \quad . \quad (15)$$

These three equations hold from $\theta = 0$ to $\theta = \theta_1$.

Second Curve.—

Referring to Fig. 9—

Lift

$$h = (r_5 - r_4) \cos (\theta_2 - \theta) + r_4 - r_1 \quad . \quad (16)$$

Velocity

$$\frac{dh}{dt} = \frac{d\theta}{dt} (r_5 - r_4) \sin (\theta_2 - \theta) \quad . \quad . \quad (17)$$

Acceleration

$$\frac{d^2h}{dt^2} = -\left(\frac{d\theta}{dt}\right)^2 (r_5 - r_4) \cos (\theta_2 - \theta) \quad . \quad (18)$$

These three equations hold from $\theta = \theta_1$ to $\theta = \theta_2$.

Dimensions.—Take $r_3 = 14{\cdot}75$ mm. and $r_5 = 24{\cdot}5$ mm. as in the preceding cases. From equation (15) it is seen that the greater the value of r_3 the greater the acceleration. In the limit when r_3 is infinite the acceleration will be infinite and the "first curve" becomes a straight line. Therefore r_3 should be as small as possible, but r_3 and r_4 must be adjusted to suit the half cam angle (in this case θ_2).

After several trials it was found with $r_4 = 2$ mm. and $\theta_2 = 58°$ that $r_3 = 221$ mm. Inserting this valve of r_3 in the lift equation (13) and putting $h = 0{\cdot}2$ mm., gives the clearance angle = 2° 27′. Hence half the cam angle = 2° 27′ + 55° 30′ = 58° approximately, and this agrees with the assumed value of θ_2. By calculation $\theta_1 = 5°$.

Inserting the appropriate data in equations (13) to (18) and substituting for different values of θ gives the lift, velocity and acceleration curves shown in Figs. 10 to 12.

Concave Cam with Increased Lift.—The convex cam with roller follower has a second curve of smaller radius than the second curve of either the concave or straight cams, and it is seen from the acceleration curves that the maximum retardation on the convex cam with roller follower is considerably greater than on the other cams. The smaller the radius of the second curve, other things being the same, the shorter time there is for the spring to reduce the velocity of the follower to zero, therefore the retardation must increase as the radius decreases.

Consider the concave cam (Fig. 5). Leaving the concave curve unaltered in radius and length, increase r_4 the radius of the "second curve" from 6 mm. to 9 mm. This will alter r_5, but the other radii will remain unchanged. That is $r_1 = 14{\cdot}75$ mm., $r_2 = 7{\cdot}5$ mm., and $r_3 = 35$ mm.

Hence $f = (r_2 + r_4) = 16{\cdot}5$ mm. By calculation $d = 17{\cdot}85$ mm. Therefore $r_5 = (d + r_4) = 26{\cdot}85$ mm.

The maximum lift = $(r_5 - r_1) = 26{\cdot}85 - 14{\cdot}75 = 12{\cdot}1$ mm.

With the normal lift concave cam the maximum lift was 9·75 mm., hence the increase is 12·1 − 9·75 = 2·35 mm., or

$$\frac{2{\cdot}35}{9{\cdot}75 - 0{\cdot}2} \times 100 = 24{\cdot}6 \text{ per cent.}$$

allowing for clearance.

As before, $\theta_1 = 22° 6′$ and by calculation $\theta_2 = 61° 5′$.

Inserting the appropriate data in equations (4) to (6) and substituting different values of θ gives the lift, velocity and acceleration curves shown in Figs. 10 to 12. Since the concave curve has not been altered the lift, velocity and acceleration are the same as before whilst the follower is on this curve.

Fig. 10. LIFT CURVES.

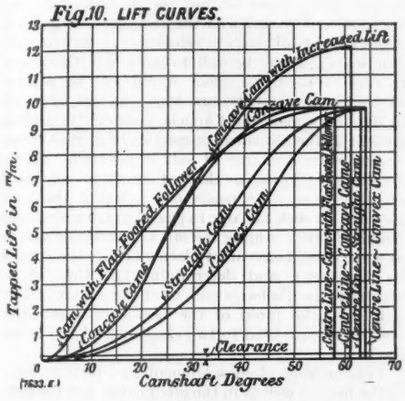


Fig. 11. VELOCITY CURVES.

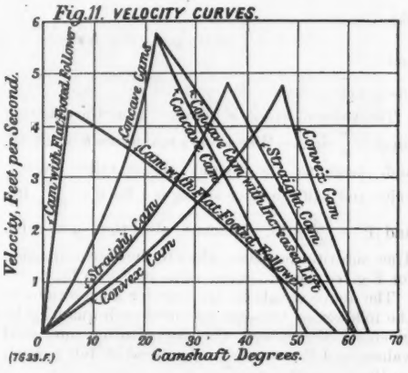
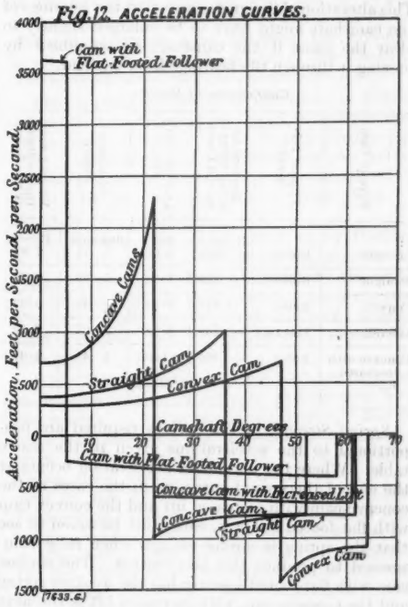


Fig. 12. ACCELERATION CURVES.



From the acceleration curve it is seen that the maximum retardation occurs at full lift and is equal to 655 ft. per second per second. At the commencement of the second curve, that is when $\theta = 22° 6′$, the retardation is 584 ft. per second per second. On the normal lift concave cam the retardation is a maximum at $\theta = 22° 6′$ and is equal to 990 ft. per second per second. Therefore increasing the lift reduces the strength of the spring required in the ratio of 990 to 584 or 100 to 59, and this is a decided advantage.

Suppose the diameter of the valve throat is D, the diameter of the valve stem is d and the theoretical maximum lift is H, then $\frac{\pi}{4} [D^2 - d^2] = \pi$ D H when the valve seat is perpendicular to the axis of the valve. Neglecting d gives H = 0·25 D and taking $d = 0{\cdot}2$ D, as is common practice, gives H = 0·24 D approximately. If the valve seat makes an angle of 45 deg. with the axis of the valve then H may be as great as 0·30 D. Generally the maximum valve lift is made less than these values, but from the point of view of decreasing the spring strength it is an advantage to increase the lift, by increasing the radius of the second curve, even above the theoretical maximum lift. There is also another advantage to be gained by exceeding the theoretical maximum lift because the higher the valve is lifted above this point the less obstruction there is to the flow of gases into or out of the cylinder,

and consequently the cylinder is filled or emptied more effectively. A report, made to the United States National Advisory Committee for Aeronautics, on "Air Flow through Poppet Valves," by Clarke Thomson Research [see ENGINEERING, Jan. 10, 1919] showed that this was so when gas passed through a valve at a uniform rate.

By increasing the radius of the second curve, and hence increasing the maximum lift the average lift is, of course, also increased. In calculating the average lift for this example from the lift curve (Fig. 10) it was assumed that $9{\cdot}75 - 0{\cdot}2 = 9{\cdot}55$ mm., gave the theoretical maximum valve lift, and the average was measured up to a horizontal line through 9·75 mm., the area above this line being neglected. It should be noted, however, as already pointed out, that some benefit is derived from the area above the line.

From the above considerations it is seen, that, instead of making a concave cam with a second curve of small radius followed by another curve which is a circle concentric with the axis of rotation of the cam giving a dwell when the valve is at full lift, it is better to increase the radius of the second curve and eliminate the dwell. These remarks also apply to straight and convex cams with roller followers if these cams are designed to give a dwell. This alteration of design suggests that the bearings of the camshaft might have to be enlarged slightly to clear the cams if the camshaft is assembled by passing it through the bearings from one end.

Comparison of Results.

Type of Cam.	Type of Follower.	Acceleration at beginning of Second Curve.	Average Valve Lift.	Clearance Angle.	Velocity when Tappet Strikes Valve Stem.
		ft./sec.²	mm.	deg. min.	ft./sec.
Concave ..	Roller ..	— 990	6·06	5 41	0·97
Straight ..	Roller ..	— 884	4·94	7 39	0·73
Convex ..	Roller ..	—1,425	4·35	8 43	0·63
Convex ..	Flat foot	— 239	6·18	2 27	2·12
Concave with increased lift	Roller ..	— 584	greater than 6·21mm.	5 41	0·97

Spring Strengths.—The springs required are proportional to the accelerations given in the above table. Where the maximum acceleration occurs at the end of the second curve, as in the cases of the concave cam with increased lift and the convex cam with flat-footed follower, care must be taken to see that the spring is strong enough when fully compressed to produce this acceleration. The convex cam with flat-footed follower has the weakest spring and the concave cam with increased lift is the next best. The straight cam is only slightly better than the concave cam with normal lift, whilst the convex cam with roller follower is easily the least desirable.

Lift.—The convex cam with the flat-footed follower gives the valve a rapid initial opening and allows it to close quickly as it returns to its seat. This cam gives the second largest average lift. From the point of rapid initial opening and final closing the concave cams are the next best. The concave cam with increased lift gives the greatest average lift, and the true value of this average lift is greater than the figure given in the table owing to the valve being lifted above the theoretical maximum opening. It should be noted also that the concave cam with increased lift raises the valve to the position of theoretical maximum opening in shorter time than that of the other cams. The concave cam with normal lift gives a considerably larger average lift than either the straight or convex cams with roller followers.

Noise.—Noise is caused by the tappet striking the valve stem on taking up the clearance. Also when the valve comes down on its seat it still has velocity which has to be reduced to zero and this reduction causes a second blow. It is assumed that when the tappet strikes the valve stem the noise is proportional to the product of the velocity and mass of the tappet and when the valve strikes the seat, as it closes, the noise is proportional to the product of the velocity and mass of the valve plus half the spring. These two velocities are of the same magnitude and may be calculated from the velocity formula. The convex cam with the flat-footed follower creates the most noise, and the convex cam with the roller follower is the least noisy as will be seen from the velocities given in the table above.

Side Thrust, Friction and Torque.—So far no mention has been made of the effect of the positive acceleration produced whilst the first curve of the cam is in operation. From the acceleration curves it is seen that, of the cams with roller followers, the concave cam produces the greatest positive acceleration and it will be sufficient to consider this cam.

The force between the cam and the roller is made up of two components, one a vertical force and the other a side thrust.

There are three vertical forces to be taken into account:—

(1) Spring force S.

(2) Accelerating force P.

(3) Frictional force F, to overcome the friction between the tappet and tappet guide caused by the side thrust.

When the roller is on the first curve of the cam the total vertical force

$$= (S + P + F)$$

Side thrust

$$= (S + P + F) \tan \phi \text{ (see Fig. 5)}$$

and

$F = \mu (S + P + F) \tan \phi$, where μ is the coefficient of friction.

The value of $\tan \phi$ is obtained from the equation $\sin \phi = \frac{a}{b} \sin \theta$. When F is a maximum $\theta = 22° 6'$, and, assuming the weight of the roller, tappet, valve and half the valve spring is 1 lb., $S = \frac{990}{32{\cdot}2}$ lb., and $P = \frac{2{,}320}{32{\cdot}2}$ lb. Assume also that $\mu = 0{\cdot}05$. Then substituting these values in the above equation for F gives the maximum value of F = 5 lb.

The above equations are true for all positions of the follower on the cam provided each quantity be given its correct sign when substituting numerical values, and if $\tan \psi$ be used instead of $\tan \phi$ when on the "second curve."

Values of F were plotted on a lift base and the horse-power calculated assuming two cams per cylinder and, as before, a crankshaft speed of 1,400 r.p.m. The result obtained was 0·0025 h.p. per cylinder. Suppose one cylinder develops 20 h.p., then the proportion of power lost in friction between the tappets and tappet guides is $\frac{0{\cdot}0025}{20} = \frac{1}{8000}$. This result shows that the effect of side thrust and the consequent friction between the tappets and tappet guides may be neglected.

Consider the torque on the camshaft when the follower is on the first curve of the cam.

Torque

$$= \frac{\text{Total vertical force}}{\cos \phi} \times (\text{Lift} + r_1 + r_2) \sin \phi \text{ (see Fig. 5)}$$

$$= (S + P + F)(h + r_1 + r_2) \tan \phi.$$

The maximum torque occurs when the vertical force is a maximum, that is when the roller is at the end of the first curve. Substituting in the above formula gives:

Maximum torque = 8·5 lb.-ft.

A shaft, 1 in. diameter, would transmit a torque of 183 lb.-ft., assuming a stress of 5 tons per square inch. Hence it may be concluded that the relatively high positive acceleration produced whilst the follower is on the first curve of the concave cam is not of great importance when considering the merits of this cam.

THE INCOR ORATED SWANSEA EXCHANGE.—The thirty-fifth annual report of the Royal Metal Exchange, Swansea, is now available, at the price of 3*s.* 6*d.* It contains a statement of accounts as at June 30 last, a list of members and of trades, together with report on the thirty-fifth annual general meeting.

RUGBY ENGINEERING SOCIETY.—This society has now issued its Vol. XV, covering the session 1920–21. Apart from an account of the general proceedings and the list of members, it contains the various papers read during the session, including "Molecular Mechanics," "X-Rays," "The Uniflow Steam Engine," and others. The book is published by the society at the price 10*s.* 6*d.*

ELECTRICAL MEASUREMENT OF VELOCITIES OF FLOW IN PIPES.

By IVAN E. HOUK, City Engineer, Dayton, Ohio.

IN the January 19, 1923, issue of ENGINEERING appeared an article by M. A. Hogen, Ph.D., entitled "An Electrical Method for Measuring the Velocity of Moving Water." This article gave a very thorough and interesting account of experiments made at the hydraulic laboratory of the Imperial College at South Kensington, in which it was attempted to develop a method for measuring the velocity of moving water by means of electricity. The experiments were made on pipes from 4 in. to 10 in. diameter, using electrodes of various shapes. They dealt primarily with variations in resistance caused by variations in the velocity of the water. The conclusion was "that although, under the particular conditions chosen, the change in resistance of a cathode, immersed in water, depends on the velocity of motion of the water, the relation between them is too variable to allow of the change in resistance being taken as a measure of the velocity."

This conclusion was undoubtedly justified. The investigations appear to have been thoroughly and carefully carried out; and they are to be highly commended. However, lest the readers of ENGINEERING should be left with the idea that the electrical measurement of water velocities is in no case practicable, it may be well to point out that there is another electrical effect which can be utilised in such measurements, one that was not taken up in the above-mentioned article, namely, the sudden change in the electrical properties of a fluid which occurs when a charge of salt is inserted. Briefly speaking, a typical method of measurement based on this principle consists of observing the time required for such a charge to pass through a measured length of pipe; adding the salt at the intake end, or at some other convenient place; noting the time of its insertion; and determining the time of its arrival at the discharge end, or at some intermediate point, by the jump of the needle of a sensitive voltmeter connected to two electrodes placed in the discharge.

This method of measurement has been utilised, in the field as well as in the laboratory, and has been found to give satisfactory results under actual working conditions. In fact, it furnished about the only satisfactory method that could be found for the measurement of dredge pipe velocities in the dredging operations carried on by the Miami Conservancy District in building the Miami Valley flood prevention dams. In these operations such heavy loads of sand, gravel and clay were being transported constantly, sometimes as much as 25 per cent. by volume, that the ordinary methods of measurements could not be used. Pitot tubes became clogged as soon as they were placed in the pipe; wooden balls could not be seen when they reached the discharge end; potassium permanganate could not be seen; and so forth. Suitable bright coloured dyes which might be visible in such a mixture could not be secured at that time, 1920 and 1921, because of the conditions growing out of the world war.

The accompanying photographs illustrate the conditions under which the Miami Valley measurements were made. Fig. 1 gives a close view of the mixture coming out of the delivery pipe; Fig. 2 shows the general pipe lay-out on one of the dams; and Fig. 3 shows a typical inside view of one of the pump-houses. Thin sheets of zinc and copper, about 6 in. long, held about ¼ in. apart, and insulated from each other and from the end of the pipe, were used for poles. These were inserted in the upper segment of the jet at the end of the dredge pipe, and were connected to the terminals of a sensitive voltmeter having a range of from zero to 3 volts with graduations for each 0·02 of a volt.

During ordinary discharge the needle indicated a difference in potential between the two poles of about 0·2 volts. When the salt solution arrived the needle jumped to about 0·5 volts, then fell again to 0·2 volts as the salt passed. While slight variations in the reading were occurring constantly, due probably to vibrations in the pipe or to pulsations in the flow, the movement of the needle caused by the arrival of the salt was so definite that it

ELECTRICAL MEASUREMENT OF WATER FLOW IN PIPES.

FIG. 1. DISCHARGE END OF PIPE WITH VOLTMETER ATTACHED.

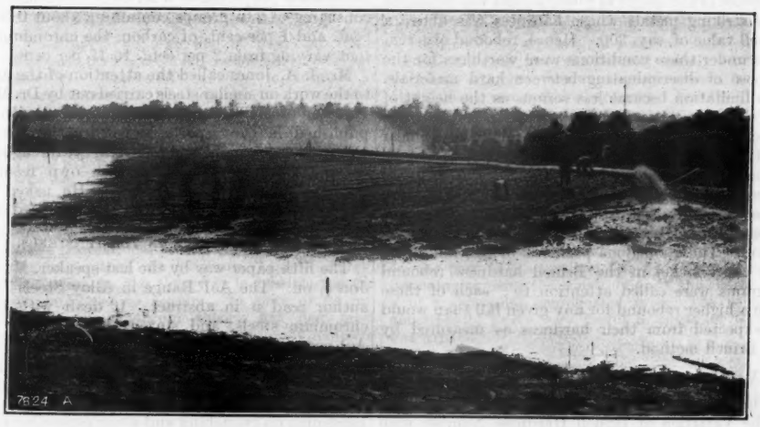


FIG. 2. GENERAL LAY-OUT OF PIPE ON ONE OF THE DAMS.

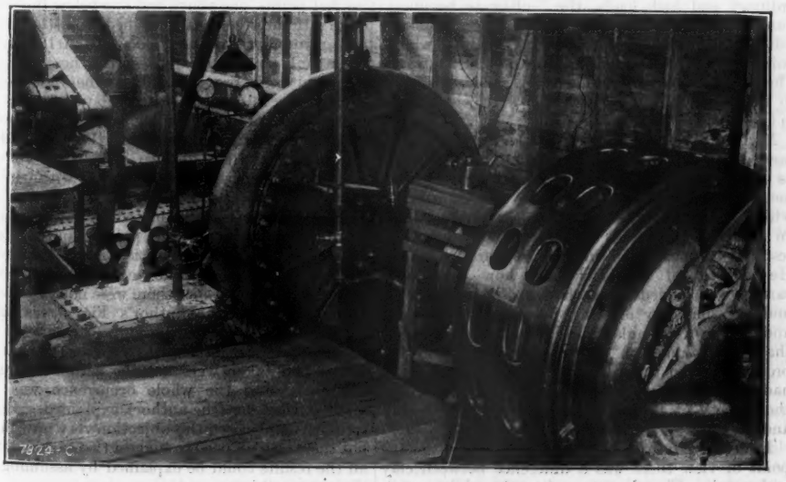


FIG. 3. VIEW IN PUMP-HOUSE.

could not be mistaken. The only uncertain point connected with the reading was the time when the needle fell back to the initial voltage. However, the time when the needle reached the maximum voltage seemed to be the proper reading to use.

A pound of salt seemed to be about the right amount when the pipe was carrying about 15 cubic feet per second. No advantage was found to result from the use of a larger dose. The salt was placed in a paper sack, and lowered over the end of the suction pipe by means of a stout cord. When the sack entered the pipe the sudden increase in velocity jerked the string out of the observer's hand, so that it was easy to determine accurately the time of insertion. Of course, the paper sack was dashed to pieces by the high velocity in the pipe, or by the pump if it held together until it reached the pump, so that the salt was thoroughly mixed with the water.

Different quantities of salt and different methods of introducing it into the pipe were experimented with, as were also different materials for poles and different chemicals for the electrolyte. The procedure outlined was found to be the most satisfactory. The accuracy of the method was tested by comparison with potassium permanganate measurements when the pipe was carrying clean water, the salt and permanganate being inserted in the intake end simultaneously, and the appearance of the two at the discharge end noted by two different observers, one watching the voltmeter needle and the other the colour of the discharge. The methods were found to check very closely.

The experimental work was carried on at different times, on two different jobs, and in 18-inch wood stave pipe as well as in the 15-inch dredge pipe. Part of the dredge pipe was riveted and part welded. The length of the lines varied from about 800 to about 2,100 feet, and the velocities from about 7 to about 18 feet per second.

The investigations were carried on by Professor S. M. Woodward, then consulting engineer for the Miami Conservancy District, assisted by the writer. At that time Arthur E. Morgan was chief engineer, Chas. H. Paul, present chief engineer, assistant chief engineer, and C. H. Locher, construction manager.

While this method of measurement has been used in determining the velocity of underground water movements, so far as the writer knows, it had not been used elsewhere for determining velocities in pipes prior to the time of its use on the Miami Valley flood prevention work. However, it was used by the Bureau of Public Roads and Rural Engineering, United States Department of Agriculture, Washington, D.C., at about the same time it was being used by the Miami Conservancy District. Since then Professor Allen, of Worcester Polytechnic Institute, has undertaken similar experiments. A brief description of some of his first work was given in the June, 1922 issue of Engineers and Engineering, page 196, published by the Engineers' Club of Philadelphia. Professor Allen's closing remarks in this article were as follows: "Although all of the experimental work thus far made gives promise of an accurate method of measuring water, yet until the work now in progress is completed, the results will not be published." Hydraulic engineers will be interested in seeing a detailed report of Professor Allen's investigations, and it is to be hoped that such a report will soon be made available.

"THE EDGAR ALLEN NEWS."—Messrs. Edgar Allen and Co., Limited, Sheffield, continue the regular issue of this publication, the present number, for May–June (Vol. 2, No. 24), containing an account of rapid delivery by the firm of a number of dredger bucket backs, articles on coal cutter picks, on granite working steels, on the fuel turbo-pulveriser installed in their press shop, &c.

MERCURY ORES.—A recent publication of the Mineral Resources Committee of the Imperial Institute deals with mercury ores. It is edited by Mr. Edward Halse, and is issued by Mr. John Murray, Albemarle-street, W., at the price of 5s. net. The sources of supply of mercury ores in the British Empire and foreign countries are reviewed in detail. The work carried out in the various parts of the world for the recovery of the mineral will be found most interesting reading.

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 615.)

IN our two last issues we reported the greater part of the proceedings at the fifty-fourth annual general meeting of the Iron and Steel Institute, held on Thursday and Friday, the 10th and 11th inst. We now conclude our précis of the papers read and of the discussions thereon.

IRON AND NICKEL ALLOYS.

The last paper taken on Friday morning, the 11th inst., dealt with "The Constitution of the Alloys of Iron and Nickel," by Dr. D. Hanson and Mr. J. R. Freeman, Junior, of the United States Bureau of Standards. It was read in abstract by Dr. Hanson. The alloys dealt with numbered 21, containing from 1·14 per cent. to 89·1 per cent. of nickel; the paper gave the equilibrium diagram of the series, and, to a larger scale, the portion referring to the iron-rich alloys, containing from 0 per cent. to 10 per cent. of nickel. The sclerosope hardness figures were also stated for a number of the alloys. The authors said that if the results in the paper were combined with those of a previous one by D. Hanson and Mrs. H. E. Hanson,* in which the constitution of the alloys at lower temperatures were described, it was possible to construct the complete equilibrium diagram for the iron-nickel system. We reproduce this paper in full on page 667 of the present issue.

Dr. Rosenhain, who opened the discussion, said the paper was the first one written in collaboration with a member of the United States Bureau of Standards. After calling special attention to the authors' diagrams and to their importance, and also referring to the light given by X-ray examination, he mentioned a very remarkable alloy in this series, the carbon-free iron-nickel alloy, discovered in the laboratory of the Western Electric Company, of America. This had been patented all over the world and was being worked extensively. It contained 81·5 per cent. of nickel and 18·5 per cent. of iron, and arrived right at the maximum in the authors' diagram, although it was not associated at first sight with that maximum. It had a strangely marked definite composition. Its properties were mainly interesting from a magnetic point of view. It became saturated under a very low magnetising force, so low, in fact, that it took a magnetising force not much greater than the earth field to saturate it completely. Its permeability was thousands of times greater than that of pure electrolytic iron. The application of a load to the material, and a mechanical stress given by hand only sufficed, led to a change in its electric and magnetic properties. Its high permeability might make it an important material in connection with the loading of telephone cables.

Dr. Hatfield found the paper of great practical value since it gave a firm foundation to work upon. He hoped the work would be extended to other binary alloys, and, if that were possible, also to ternary alloys; for example, to iron-carbon-nickel.

Colonel N. T. Belaiew also pointed to the importance of the authors' diagrams and to the difficulties which they solved.

Professor F. C. Thompson stated that the authors' work was above criticism and expressed his satisfaction that it had been carried out in an English laboratory. The first diagram by Dr. Hanson and Mrs. Hanson was a most useful one, and now there was a complete diagram as a basis to work from. He thought the authors' suggestion as to the relation between the minimum in the liquidus and the maximum in the solidus rested solely upon a coincidence. Examination by X-rays did not show whether a compound were present or not; that was, so far, a weakness of X-ray examination. With regard to the space lattice and the alloy mentioned by Dr. Rosenhain, there would not appear to be any relation between the space lattice and magnetic properties; the space lattice, Professor Thompson added, had nothing whatever to do with the magnetic properties. In conclusion, he (the speaker) said that the authors' work was the most remarkable that had been done for a long time in this direction.

* See ENGINEERING, vol. cx, pages 413, 620 and 655.

In the course of his reply, Dr. Hanson thanked Dr. Rosenhain for the information he had given on the American 81·5 nickel and 18·5 iron alloy, which appeared to be a most important one. In regard to the magnetic properties not being related to the phase changes, this seemed to be true, but the changes in the atoms might come in. They were at the present time dealing at the National Physical Laboratory with a large number of alloys of the binary system. The iron-nickel alloy was the simplest in actual construction and from the point of view of experimental difficulties; they could not as yet make any promise in the matter of ternary alloys for an early date. He agreed with Professor Thompson that it was not certain whether the minimum in the liquidus and maximum in the solidus were both at the same temperature, or even connected, but he (the speaker) was able to add that the work carried out and described in the paper did not afford a proof that the compound Fe Ni2 existed in this connection. He thought that the X-rays most certainly could explain that a compound was formed, although in some they might not, namely, where, for example, there were uniform solid solutions.

HARDNESS.

The first paper taken on Friday afternoon was entitled "A Contribution to the Study of Hardness," by Professor C. A. Edwards and Mr. C. R. Austin. It was read in abstract by the latter. The paper stated that there did not appear to be any simple relationship between the rebound method of measuring hardness and the Brinell static method; it was not, therefore, readily possible to express one in terms of the other by the use of a conversion scale. If small amounts of energy were used in the drop test, there was comparatively very little difference in the height of rebound that was produced after striking metals whose hardness was above a Brinell value of, say, 300. Hence, rebound observations under these conditions were worthless for the purpose of discriminating between hard materials. This limitation became less serious as the height of fall was raised, and there appeared to be some reason for considering that there might be a linear relationship between the rebound and Brinell values if the height of fall were increased to an extent which had not yet been ascertained. This state of affairs was approximately reached when using a 10-mm. steel ball, if the height of fall were 75 cm. The anomalous positions of tin, mild steel and cupro-nickel in the Brinell hardness rebound diagrams were called attention to; each of these gave a higher rebound for any given fall than would be expected from their hardness as measured by the Brinell method.

VARIATION OF BRINELL HARDNESS NUMBER.

The second paper was by Mr. Hugh O'Neill, on "The Variation of Brinell Hardness Number with Testing Load." It was read in abstract by the author, and reviewed the Brinell number at low, ordinary and high loads, the "ultimate hardness number," the maximum Brinell number, tests on soft metals, viscous materials, &c., all of which points do not lend themselves to a brief abstract. The author, in presenting his paper, called attention to the work carried out by Mr. Okubo, of Tokio, in the same field.

Mr. A. S. E. Ackermann stated that he had carried out experiments upon clay at the same time as Professor Edwards was making his own using metals, and, speaking generally, the agreement which he found between the two was remarkable. In his (the speaker's) work, steady pressure was resorted to, using an inverted square pyramid. He showed on the blackboard how his weight carrier was loaded on each side and all round, and the similarity existing between the author's and his own formulæ. The experiments proved that the volume of clay displaced was directly proportional to the work causing penetration. He had given his experimental results in a paper to the Society of Engineers; they covered both clay and metals.

Professor Edwards, in replying, said that from one point of view there was a difference between clay and metals. Clay flowed consistently, whilst metals apparently developed a great capacity to resist continued penetration. There was a work-hardening effect which came in. With reference to Mr. O'Neill's "ultimate hardness number," did he mean by that expression the hardness of the metal after a certain diameter was passed, when the ball then proceeded through the material? He (the speaker) thought Mr. O'Neill must have omitted some factor. A dead-rest was always arrived at, except perhaps with lead. For a metal that could work-harden the point did not seem to apply.

Mr. Ackermann here interposed that his own experiments would explain the point in question; it was only necessary to change the scale, then his work would apply both to clay and to metals.

COLD-WORKING OF STEEL AND THE TENSILE TEST.

The third paper taken on Friday afternoon was on "The Cold-Working of Steel with Reference to the Tensile Test," contributed by Mr. John Stead, who read it in abstract. This paper was not discussed. The experiments it described were undertaken in the first place with the object of finding some relation between the tensile strength of wire and that of the steel from which it was drawn. No definite relation was obtained, but some of the results arrived at and given in the paper were of interest from the point of view of cold-working generally. The data were sufficient to justify qualitative conclusions; but to obtain accurate quantitative values, many more experiments, the author stated, would be required.

CHROMIUM STEELS.

The fourth paper was on "Some Mechanical Properties of a Series of Chromium Steels," by Mr. Ch. R. Austin, who read it in abstract. It recorded the effect of heat-treatment on the mechanical properties of a series of chromium steels consisting of two groups containing about 0·35 per cent. and 1 per cent. of carbon, the chromium content varying from 2 per cent. to 12 per cent.

Mr. J. A. Jones called the attention of the author to the work on similar steels carried out by Dr. Moore, Director of Metallurgical Research, Woolwich, and published in the reports issued by the Research Department, commencing several years ago, and asked the author to consider his own results in reference to Dr. Moore's work. He asked what were the rates of cooling for the annealed steels.

THE Ac1 RANGE IN ALLOY STEELS.

The fifth paper was by the last speaker, Mr. J. A. Jones, on "The Ac1 Range in Alloy Steels"; the author read it in abstract. It dealt with nickel-chromium steels, and stated that in alloy steels Ac1 occurred over a range of temperature. Soaking within this range resolved the carbide into conjugate mixtures, one of which dissolved. This partial solution of carbide was associated with partial hardening on quenching and a corresponding change in microstructure. After soaking within the Ac1 range, and cooling below the Ar1, the steel gave two Ac1 points, one above and one below the normal point. If the steel was quenched from the soaking temperature, or was not cooled to Ar1, only the upper Ac1 point appeared on the heating curve. In certain steels, provided diffusion had not occurred above Ac1, a steel normally showing only Ar1 showed two points on cooling. Annealing restored the steel to its original condition. (We may add that the paper referred to two Woolwich Research Department Reports, Nos. 55 and 57, with which we dealt on pages 502 and 520 *ante*.)

Dr. D. Hanson congratulated the author on the interesting changes he had pointed out as taking place through the lower critical range. In regard to the theoretical part, however, he (the speaker) disagreed with him, since there were not two carbides in these steels. The author's Fig. 5, showing a section through the eutectoid transformation was, he thought, an arbitrary selection. What the author had taken were not the actual carbides in the steels, and the whole occurrence was more complex than he (the author) explained. He (the speaker) emphasised this objection very unwillingly, but there was no need to suggest two carbides, when all the results could be explained by assuming that there was only one.

Mr. J. A. Jones was afraid there was a mis-

apprehension on Dr. Hanson's part, and he did not follow the bearing of his statement. He (the author) did not say there were two carbides, but ferrite and an isomorphous mixture of iron and manganese carbides and, when the steel was held at a given temperature within the range, partial solution of the carbides occurred. He added that the carbide which passed into solution was not of the same composition as the original mixture, but contained more manganese carbide. This left undissolved carbide, and so forth. A definite case was found in manganese steel. It was an isomorphous mixture of carbides separating out.

IMPACT TESTS AT DIFFERENT TEMPERATURES.

The last paper, by Mr. F. C. Langenberg, Watertown Arsenal, United States, was read in brief abstract by the secretary. It was entitled "An Investigation of the Behaviour of Certain Steels under Impact at Different Temperatures." The steels investigated were those in common use and representative of the types employed in the construction of ordnance and automotive machinery. The tests were made with a Charpy pendulum machine of a capacity of 2,170 ft.-lb. The tensile specimens were tested on the United States Government testing machine at Watertown Arsenal, and the Brinell tests made with an Alpha Brinell machine using a 10-mm. ball and 3,000 kg. pressure. The method of taking the temperatures was described, and the results tabulated. We propose to reproduce this paper in abstract in a forthcoming issue.

The other papers on the list were taken as read, and all the authors received the thanks of the meeting for their contributions. The usual thanks to the Institution of Civil Engineers for the loan of their premises concluded the proceedings.

NOTES ON NEW BOOKS.

THE quantum hypotheses, due to Max Planck, has proved at once both exceedingly fertile and exceedingly unsatisfactory. Expressed broadly it implies an atomisation of energy. Thus on this view a molecule of hydrogen can only rotate at certain definite speeds, the kinetic energy of rotation being always a whole multiple of a certain unit energy. The mind fails to picture how the passage from one speed to the other is achieved, yet the fact is unquestionable that the hydrogen molecule does behave in accordance with this view. Experiment shows that it apparently loses the power to rotate at very low temperatures, at which the average translational kinetic energy of the moving molecules is less than the minimum "spin" energy, which according to the theory it is possible for the hydrogen molecules to acquire. In spite of its unintelligibility the quantum theory has had most remarkable triumphs, and a concise but pretty complete account both of its successes and failures will be found in Fritz Reiche's "*The Quantum Theory*," of which an English translation by Messrs. H. S. Hatfield and Henry L. Brose has been issued by Messrs. Methuen and Co., Limited, at the price of 6*s.* net.

In commencing any new study the possibility of making a preliminary general reconnaissance of the ground to be covered is of very great advantage to the student. This is particularly the case with the calculus, where the beginner is called upon to assimilate an entirely novel set of ideas and considerations. The effecting of differentiations is an art easily acquired, but the novice though he finds no difficulty in getting correct answers, commonly finds himself wondering as to what it is all about. To meet the needs of such and of those who wish to understand this without aspiring to become experts, Mr. G. W. Brewster, M.A., senior mathematical master of Oundle School, has prepared a little volume entitled the "*Common Sense of the Calculus*." This is published by the Clarendon Press at 2*s.* net. The only mathematical knowledge demanded from the reader is a little elementary algebra and geometry. The author states that this presentation of the subject has been found both intelligible and interesting by boys of 14. Naturally and most properly there is no attempt at "rigour," the need for which only makes itself felt in advanced work where functions have to be dealt with which often have little connection with anything in the heavens above, the earth beneath, or the waters under the earth. The concept of small quantities of different orders, constitutes, in fact, far the simplest and most intelligible basis on which to present the calculus to the beginner.

In harmonic analysis, that is, in the development of a periodic curve into a Fourier series, various expedients are resorted to for the purpose of facilitating the laborious calculations of the coefficients which involve the summation of integrals. The period is subdivided by ordinates, the ordinate values and certain products are entered in horizontal and vertical rows on separate sheets, and a selection of the terms to be summed up is sometimes made with the aid of stencil plates, one for each coefficient, from which certain squares are cut out according to the curve. The stencil plates being expensive, Dr. Ing. L. Zipperer, in his "*Tafeln zur Harmonischen Analyse Periodischer Kurven*" (Berlin: Julius Springer; price 4*s.* 2*d.*) uses sheets of tracing paper for the fundamental tables, and further white sheets with red squares in different groupings, instead of the stencil plates. The former sheets are replenished by the publishers, the latter may be re-used. Dr. Zipperer, of Gelsenkirchen, near Essen, states that he has found his tables, which are supplied in a folder, convenient for use by unschooled computers.

The education of the old-time mechanic, who could not read or write was pretty well confined to directly useful subjects. To-day the Board of Education in its arrangements for technical classes, has been more and more prone to lay stress on such studies as may be immediately serviceable in industry. This procedure is perhaps justified in the case of the average student, and it is somewhat the fashion nowadays to sacrifice the brilliant man to those of more ordinary abilities. It is unnecessary to discuss here the wisdom of such a policy, but taking it as it stands the needs of the average student are specially catered for in the Directly Useful Technical Series published by Messrs. Chapman and Hall, Limited. Two recent additions are "*Arithmetic for Engineers*," by Mr. Charles B. Clapham, B.Sc., and "*Line Charts for Engineers*," by Mr. W. N. Rose, B.Sc. The book first named is published at 7*s.* 6*d.* net, whilst the price of the second volume is 6*s.* net. The arithmetic by Mr. Clapham is a third edition, and now includes a chapter on elementary trigonometry. The author makes, at the outset, a very limited demand on the mathematical knowledge of his readers, and proceeds from this by easy steps up to more advanced work. Chapters on Mensuration and on the use of logarithms, and of the slide rule, are included. The illustrative examples are derived largely from shop problems and there are numerous exercises, by which the student can test his progress. Mr. Rose's book describes more particularly the construction of alignment charts which, originated by M. D'Ocaque some thirty years ago, are steadily growing in popularity. Indeed, they often provide by far the simplest and best means of applying formulas of a complicated type, as the accuracy attainable is generally ample and the risk of numerical errors is avoided. Unfortunately it is not all formulas which are reducible to such charts. Mr. Rose assumes very little mathematical knowledge on the part of his readers, but by quite elementary reasoning explains the construction of the charts, even if of a somewhat complicated type. The book will undoubtedly prove very useful to those for whom it was written.

There is no need to say much more about so old-established and deservedly popular a handbook as the "*Hütte, des Ingenieurs Taschenbuch*" than that Volume I of the 24th edition is before us (Berlin: Julius Springer; price 9*s.*) The first volume deals with mathematics, mechanics and machinery, heat and materials. Some well-known experts like Professors R. Mollier, A. Laskus and M. Weber, and Dr. Ing. M. Tolle, remain among the contributors; Professor O. Dziobek (mathematics) has died since compiling his section. The sections on heat, strengths (especially also of flying machines), lubrication and belting have been considerably enlarged, the section on the mechanics of solid bodies has been re-written, and the volume has swollen into 1,308 pages. The "Hütte" was first published in 1857, in three parts; afterwards the whole three main divisions were collected in one or two volumes, but a return to the three volumes was soon made. To meet the financial distress the three volumes are now separately obtainable, which was not possible previously.

Accurate data with regard to merchant ships are of such importance to the large section of the community in this country whose business is directly connected with shipping that careful attention must be given to any new source of information. Much can, of course, be learned about ships by reference to Lloyd's Register, but this valuable work does not contain all the information which might be useful to business men, and Messrs. F. C. Bowen and F. J. N. Wedge, in their "*Merchant Ships of the World*," which is published by Messrs. Sampson Low, Marston and Co., Limited, have endeavoured to supply the deficiency. In the first section of this work, which is naturally rather bulky, containing nearly 500 quarto pages, the fullest available particulars of all merchant ships of over 1,000 registered tons are given, and, in the second section, the vessels are all classified in a manner intended to facilitate their identification at sea. The first section is divided into sub-sections for each nation, and in these sub-sections the vessel's name appears under the name of the owners, arranged in this case alphabetically. For each ship the date of construction, tonnages, draught, speed, length and rise of floor are given, together with particulars of the holds, hatches, cargo capacity, cargo-handling appliances, passenger accommodation, machinery, fuel capacity, daily fuel consumption, &c. A large number of vessels are also illustrated by small reproductions of photographs, in order to show their general appearance and, in addition, a complete index to names is given in order to facilitate reference. To identify a particular ship at sea with certainty is by no means a simple matter owing to the great similarity between different vessels of the same type, but the problem seems to have been simplified as far as possible in the work we are considering. The numbers of funnels and masts and the general form of the hull are used as the main elements for identification purposes, and nearly 200 classes are formed from these main elements in various combinations with different minor features. Each class is further divided in accordance with the colouring of the funnels, under which heading the vessel's name appears, together with such special characteristics as should suffice to establish its identity. In general we may say that very great care seems to have been exercised in the compilation of the volume, which must have involved particularly heavy work. Its revision, if, as we presume, it will be issued at regular intervals in the future, will be no light task, and no one will be better able to appreciate this than the shipowners, shipbuilders, shippers, charterers, salvage companies, underwriters, &c., to whom it will be particularly serviceable. The publishers' address is 100, Southwark-street, London, S.E. 1, and the price of the book is three guineas.

It is so much easier to learn how a thing is done than how to do it, that there is a great tendency at the present day to exalt academic instruction at the expense of practical training. Book work alone will never make an engineer, and much less will it teach the art of handling men which is so essential in many branches of engineering. From the university graduate in honours at one end of the scale down to the ambitious youth who puts a cross opposite the profession he would like to enter and then takes an advertised course of lessons by post, no man can master a constructive art like engineering without acquiring the most essential part of the knowledge by practical work under commercial conditions. This being understood, books then take their proper place in an instructional course, and in "*Mine Management*," by Robert Z. Virgin (London: Sampson Low, Marston and Co.; price 6*s.* net), students will find a sensible and easily-read handbook dealing with the duties of a mine manager and his relationships with the men. The author, now assistant professor of coal-mining at the Carnegie Institute of Technology, Pittsburg, worked for twenty-five years as fireman, under-manager and manager of coal mines, so that his writing has a distinctly practical tone. The book is printed in England and has apparently been edited for English readers, but now and again one finds expressions which indicate its origin.

In his "*Leistungs steigerung von Grossdampfkesseln*" Dr. Ing. Friedrich Münzinger, of Berlin, discusses in an instructive manner the means by which the output of large boilers can be increased, with special regard to tubular, more or less vertical, boilers, and their furnaces and circulation. We are still being treated to claims of high thermal efficiency as based upon trial runs which give little information as to safety and simplicity of working and general economy. Dr. Münzinger bears these general requirements well in mind in his deductions and critical comments on a large number of notable boiler installations, English and American as well as Continental, pointing out with the aid of the 173 diagrams and views illustrating his volume of 163 pages (Berlin: Julius Springer; price 6*s.* 3*d.*), *e.g.*, how a boiler should be set so as to do double duty without endangering the furnace walls—mainly by facilitating heating by radiation—what materials should be used, and how waste heat can be utilised. In his concluding chapter he advocates steam storage on the Swedish Ruths system and boilers of very high pressures as quite recently constructed by Wilhelm Schmidt (ordinary tubular boiler) and by the Swedish Atmos Company (tubes rotating about their longitudinal axes). In these comments more is said about the structural difficulties than about the advantages of pressures of 800 lb. and 1,500 lb. per square inch.

UNIVERSAL BAR COAL-CUTTER.

CONSTRUCTED BY MESSRS. MAVOR AND COULSON, LIMITED, ENGINEERS, GLASGOW.

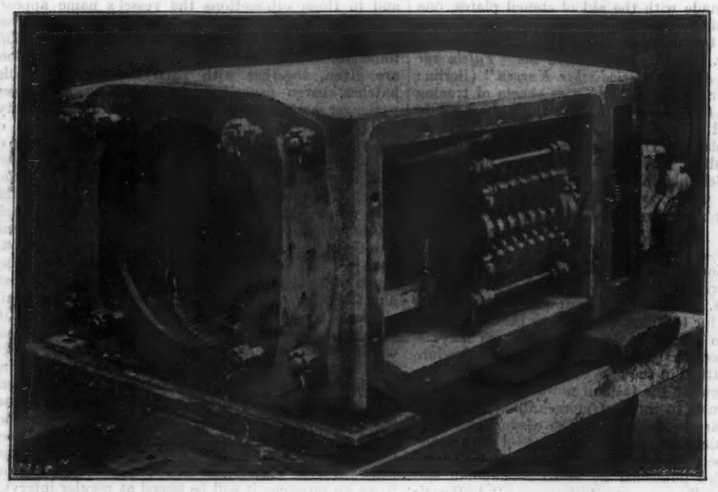


FIG. 12. STATOR OF A.C. MOTOR SHOWING SWITCH IN POSITION.

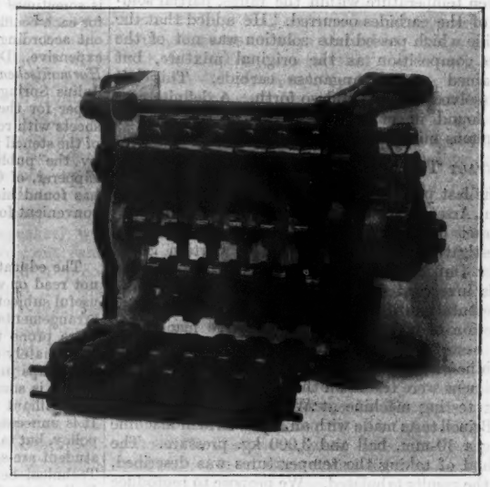


FIG. 13. SWITCH FOR A.C. MOTOR.

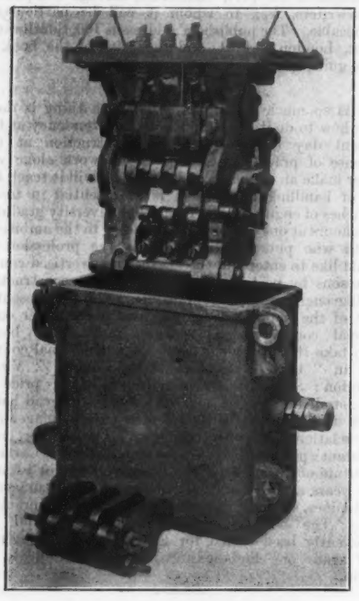


FIG. 14. OIL BREAK SWITCH FOR A.C. MOTOR OF COAL-CUTTER.

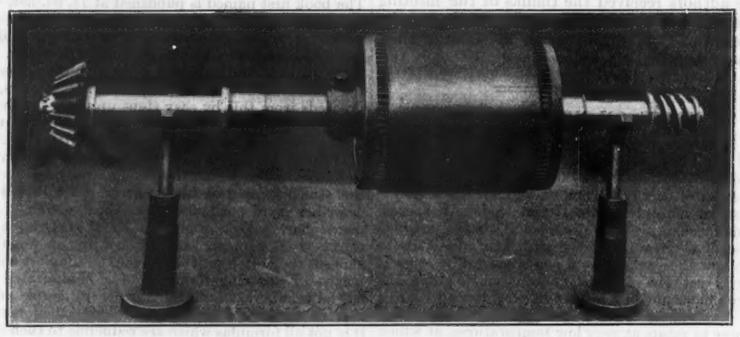


FIG. 15. SQUIRREL CAGE ROTOR FOR A.C. COAL-CUTTER MOTOR.

MAVOR AND COULSON COAL-CUTTERS.

(*Concluded from page* 616.)

THE alternating-current power unit is a three-phase electric motor of the squirrel-cage type, and wound for the standard pressure of 500 volts and 50 cycles, or for any pressure between 200 volts and 600 volts, and any frequency between 25 periods and 60 periods per second. The stator, Fig. 12, is completely enclosed and protected from damage, and from the entry of dust, and is flameproof. The main casing also contains the starting switch. As it is important to keep down the vertical height of the power unit to a minimum and the diameter of the rotor must be made as large as practicable, the bottom coils of the stator must be set as low as possible. In this position they are liable to damage from oil, but this is prevented by the provision of lodgement spaces for waste oil from which it can be drained through plugs. On the opposite side of the stator to the switch there is a similar space for the accommodation of hand tools and other small accessories. The switch, which is illustrated in position on Fig. 12 and in the separate view in Fig. 13, is of the quick-make and break type, with a rotary controller. The fingers are of the hinge pattern and have heavy, renewable copper tips. Helical springs are used to supply the required pressures. The finger bases are clamped to steel rods insulated by micanite tubes. The barrel contacts are clamped to the square steel spindle and insulated from it by a heavy micanite tube. The finger bars and spindle are supported in cast-iron end frames held in position by heavy steel stay bolts. Barriers of highly refractory material, assembled on steel rods clamped to the end frames, are interposed between the fingers. The fingers are arranged in sets of two connected in parallel, one being above and the other below the barrel. By this arrangement very large current carrying capacity and the possibility of breaking a very heavy supply are obtained in a restricted space. It is not always considered necessary to instal oil break switches, but when it is desired, the form shown in Fig 14 is used and the equipment is fitted in the space on the stator, which is usually occupied by the air break type. The same methods of construction as used with the standard type, are adopted in the oil-break switch. The rotor, with the bevel wheel and worm on the ends of the shaft which are used for driving the main gear and the haulage equipment respectively, is illustrated in Fig. 15. Tunnel slots formed in the core plates contain the solid copper bars, which are united at their ends and thus short-circuited by rings of copper.

The direct-current unit, which is compound wound and designed for the standard voltage of 500, or any desired supply pressure between 200 volts and 600 volts, has many interesting features. From the illustration, Fig. 16, it will be seen that the steel magnet shell is of rectangular cross-section and that the two pole pieces with their coils attached are removable and thus allow the inspection of the armature from end to end. The space occupied by the switch in the alternating current unit is similarly used for the barrel switch in the direct-current type, but the space at the other side of the machine is, in this case, occupied by the starting resistance. The switch and its resistance are shown apart from the machine in Fig. 17. The cables from the switch are carried inside the casing of the power unit and pass through an insulating channel supported from the roof of the magnet shell. The switch is built up on a steel spindle and insulated throughout with mica. For the resistance unit rectangular sheets of resistance metal are interleaved with mica. It is divided into an upper and lower section, each of which is compressed and secured by its own clamps. The sections are mounted on cast-iron end-frames and bolted in the same manner as the switch to the floor of the shell. The resistance is divided up into five sections, each of which may be cut out as the switch is advanced another step. The armature, with its commutator, built up on the driving shaft which is provided with the worm and bevel wheel for operating the coal-cutter, is shown in Fig. 18.

Until some few years ago all coal-cutters making use of compressed air were fitted with reciprocating power units. These, because of the necessary limitation of dimensions, had to run at very high speeds. Under the conditions imposed on their working, in the hands of men who were not always considerate in the operation of their machines, frequent overhauls and repairs were necessary. With the introduction of a satisfactory air turbine the reciprocating motor lost much of its popularity. The air turbine is not exactly a novelty, but the requisite accuracy in workmanship necessary for its efficient working was only attainable with the introduction of precision working in engineering factories. Although machining operations in its construction and adjustments of a high degree of accuracy are required for the production of satisfactory economy, the air turbine is really a simple and sturdy piece of plant.

The power unit again occupies the space between the gear head and the haulage gear. The rotors consist of two hollow cylinders with double helical teeth cut on their surfaces and meshing with each other.

UNIVERSAL BAR COAL-CUTTER.

CONSTRUCTED BY MESSRS. MAVOR AND COULSON, LIMITED, ENGINEERS, GLASGOW.

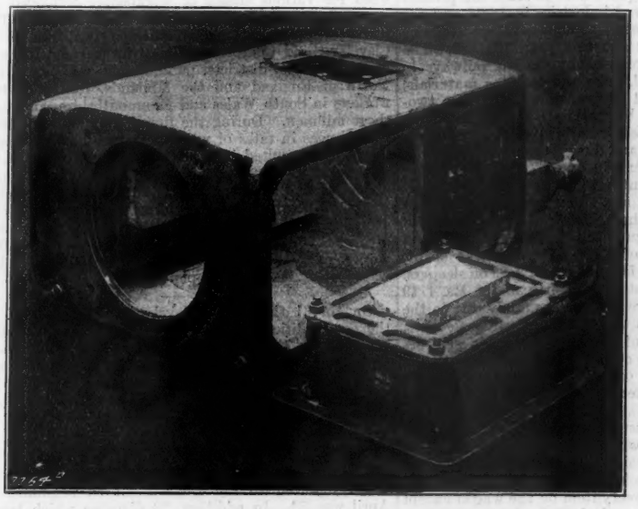


FIG. 16. DIRECT-CURRENT MOTOR FRAME SHOWING POLES AND SWITCH.

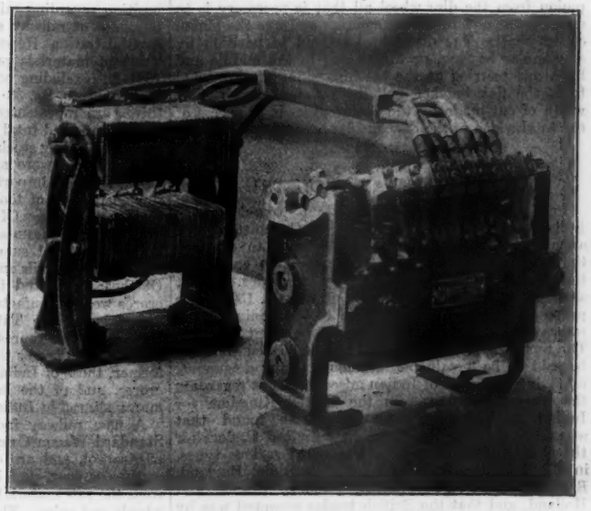


FIG. 17. SWITCH AND RESISTANCE UNIT FOR D.C. COAL-CUTTER MOTOR.

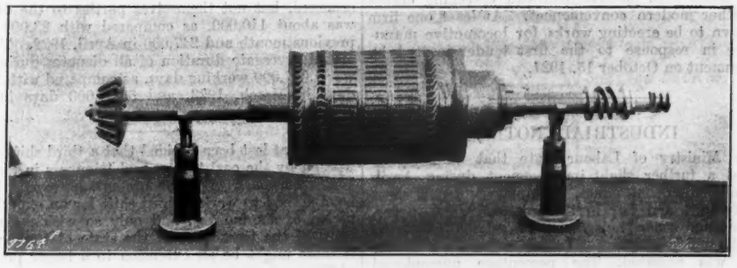


FIG. 18. ARMATURE OF DIRECT-CURRENT MOTOR FOR BAR COAL-CUTTER.

They are shown with the associated gear in Figs. 19 and 20, on page 656. A view of the complete coal-cutter is given in Fig. 22. The casing is bored out to give suitable enclosing cylindrical spaces in which the rotors may revolve. Cylinder heads close off these spaces and carry the ball bearings for the rotor shafts. The air enters through ports cut at each side of the central ridge between the two cylindrical faces, Fig. 21. It passes into the V spaces formed by the teeth of the rotors and by its pressures forces the two rotors to turn away from each other at the bottom of the cylinders. As the space left for the air to occupy continuously increases, the pressure falls, and this expansion continues until the air can escape through the ports cut through the top of the cylinder casing.

Fig. 23, on page 656, is a sectional plan of the turbine and shows the bearings in place. The clearances between the cylinder walls and the rotors must be kept down to as low a value as permits their free rotation. If after working for some time the clearances have been increased the adjustment to suitable working conditions is still possible because new holes may be drilled on the cylinder heads for the dowel pins holding the bearings in position. For this work the radial adjustment can be made by inserting strips of paper 0·006 in. thick and about 4 in. wide between the rotors and the cylinder at each end. Afterwards the cylinder heads, with the dowel pins removed, are bolted in position with care so that the rotor is not disturbed. New dowel pin holes are then bored and reamered, after which the cylinder heads are dismantled for the removal of the paper strips. As their teeth mesh it is only necessary to locate one of the rotors axially. The double thrust bearing at the left-hand end of one of the rotors is used to control the actual setting. A washer plate sits between the double ball-race bearing and the centre plate of the thrust block. This washer must be accurately machined to give the required clearance, and if too thin must be replaced by a new one.

The drive to the bar, Fig. 20, is taken through a pinion on whichever rotor shaft gives the required direction of rotation. Otherwise the drive to the bar is similar to that used with the electric plant, which has been already described.

For haulage operation a short shaft receives motion from one of the rotors by a spur wheel drive and has a worm on its other end to actuate the gear, Fig. 19. The actual haulage is by a flexible steel rope which can be wound on a drum. Two speeds are available. The first is an adjustable slow-speed for feeding the machine when cutting, and the second is a fixed higher speed for flitting. The slow speed is operated from the worm on the power unit shaft, which drives a worm wheel on the disc shaft, which is situated below it. At the other end of this lower shaft a disc is forged solid with it and is slotted to carry a crank-pin, the position of which in the slot may be varied to give different strokes. From this pin motion is taken by a connecting rod to two rocking levers, between which the driving pawl is mounted. This pawl engages with a ratchet wheel connected through a cone clutch to a cross-shaft which carries a pinion working with the spur wheel on the rope drum. By this arrangement the speed of the motor shaft, about 1,000 r.p.m., is reduced to about 2½ r.p.m. for the drum. A complete device, not visible in the illustration, is used to adjust at any time the rate of feed given by the gear, even while the machine is running. The clutch is formed by a cone on the shaft (see general sectional plan, Fig. 2, on page 614 *ante*) upon which the ratchet wheel is mounted. The clutch is operated by a star nut, a tap with a hammer being sufficient to put it into or out of operation. The high-speed haulage gear is an independent unit which can be fitted to the standard machine in about half an hour. It is operated by a supplementary worm on an extension of the forging on which the worm of the slow-speed haulage is formed. Rope guide pulleys are fitted at the back of the machine to facilitate manœuvring the machine by its haulage rope.

The results of the experience of one firm working a 4-ft. 3-in. coal seam were given to the manufacturers of the coal cutters and published in their excellent little monthly journal *M. & C. Machine Mining*. In this work the bar type of machine was used and operated to a depth of 5 ft. 9 in. to 6 ft. of undercutting. The lineal miles cut by each machine each year averaged 8·8, equivalent to an area of cut of 6·1 acres and giving a yield of 37,764 tons. The haulage rope lasted approximately four months, or during the time of cutting about 3 miles. New cutter picks to the total number of 1,076 each year were introduced, so that each pick cut on an average over 35 tons before it was necessary to scrap it. The replacement of machine parts amounted to approximately 8 per cent. per annum of the first cost of the equipment.

Although the most suitable type of coal-cutter for a given piece of work may be selected with some approximation to certainty it is not possible to predetermine what will best suit the conditions that may develop in the working of a seam. For instance, a chain machine may be suitable for the early stages of working a longwall face, but after the work has advanced weights may be brought to bear on the coal edge and cause collapse of the coal on the chain jib. Change to the bar type will then be necessary. Again the bar machine may be applied with advantage in rapidly opening out a seam by deep undercutting, whereas when the stage of longwall working with shallower undercut is reached replacement of the bar machine by one of the chain type may be advisable.

The standard bar type of machine may be readily transformed into a chain coal-cutter by removing the gear head and replacing it with a suitable chain one. The general arrangement of the chain coal-cutter is shown in Fig. 24, on page 656. Motion is taken from the bevel pinion on the end of the motor shaft to a large bevel wheel, mounted on a heavy spindle much in the same way as was seen with the bar machine. The hub of the bevel wheel, which is provided with two long keys, enters the bore formed in the extension of the hub of the sprocket spindle. The chain is built up of double pick boxes, except in the case of those for the centre picks. The thrust of each pair of picks is balanced and the boxes and the chain rail are relieved of the side pressure and excessive wear that attend the use of single pick boxes in hard cutting. The cutter picks and the devices used for their fixing in position on the chain were described recently in ENGINEERING (see vol. cxiv, page 726).

The disc coal-cutter was the first of the existing types of coal-cutters for longwall working. This machine is particularly suitable for cutting to a moderate depth in the hardest cuttable materials where the conditions are such as to make the operation of longwall machines possible. In such work the disc coal-cutter will travel faster and cut more in a shift than any other type. It is not suitable for work where the roof is tender, the coal friable and horizontally stratified, where there are faults or where the holing must be made at any position more than a few inches above the floor.

In this type of machine, which is illustrated in Fig. 25, on page 656, the motor, electric or compressed air, occupies the one end of the coal-cutter and

the haulage gear the other, the drive to the disc being located in the middle. The driving pinion is fitted to a coned shaft and held in position by a clutch with four jaws fitting into recesses in the pinion. While working, the clutch is held in position by a nut screwed up on a projection of the shaft. To disengage the pinion from the disc wheel all that is necessary is to unscrew the nut, remove the clutch and free the pinion on its shaft. The disc wheel is held in position by an annular bearing, or thrust ring in the middle and by a quarter ring at the machine side, all supported from the flat bracket bolted to the machine. The width of cut made by the cutter picks is in excess of the total width of the disc and its bracket.

INDIAN RAILWAY INDUSTRIES.

IN accordance with a resolution passed in the Indian Legislative Assembly, a Committee was appointed by the Government of India to consider the steps to be taken by Government to encourage the establishment of the necessary industries, so that as large an amount as possible of the Rs. 150 crores proposed to be set aside for the reconditioning of the railways during the next five years, be spent in India. The report of the Committee is now published and may be said to be a valuable and illuminating document, removing a number of Indian misconceptions regarding the purchase of stores in the United Kingdom for Indian requirements. The Committee found that when the Railway Board recently invited tenders for the supply of 3,132 railway wagons of various types, in all 44 tenders were received from India, England, Belgium, Germany, America, Canada, France and Holland, and that the British tender accepted was by far the lowest and was half a crore cheaper than the lowest quotation received from any tenderer in India. The reason is to be found in the superior organisation and long experience of the overseas firms. Such industries as the manufacture of railway engines and wagons require years for their development. In India the necessary labour for such work is extremely limited and would take long to train, the production costs would be high while the initial out-turn must be small and uncertain. The Committee point out that the British firm which obtained the bulk of the order has an authorised capital of 11,000,000*l.* and is a combination of numerous old-established engineering concerns which between them manufacture almost every part of a wagon from the initial pig iron to the final paint.

In due consideration of this limitation, the Committee are of opinion that the most hopeful solution of the problem lies in continuing the method of the Government of guaranteeing orders to encourage a new industry, to be applied with discretion so as to safeguard price, quality and delivery, the guaranteed price to be the c.i.f. price of the similar imported article, plus import duty. In this connection it has to be remembered that these industries are based on the steel industry, the soundness of which is therefore a condition precedent to the establishment in India, of the manufacture of wagons and locomotives on really sound and healthy lines. At present, the firms now building wagons in India are dependant on imported steel to the extent of 80 per cent. of their requirements. Now if, according to the recommendation of the Fiscal Commission, the Tariff Board which the Government hope to establish come to examine the question of extending protection to the steel industry and decide in its favour, there may arise a conflict of interest, initially at any rate, between the steel industry and the wagon industry. In consideration of this difficulty the Committee recommend that if a Tariff Board is constituted and is advised to examine the question of protection to the steel industry, it should be instructed also to investigate the wagon, locomotive and similar industries, and to consider the bearing on such industries of any proposals it may make in respect of steel.

Two minutes of dissent are appended, one signed by four members, and another signed singly by Sir Campbell Rhodes. The first demands immediate protection to the steel industry on the ground that though ordinarily in the interest of the taxpayer it is best to buy in the cheapest market, in the long run the taxpayer and the country will be a loser, if the existing Indian enterprise in wagon building is allowed to be killed by foreign competitors for want of encouragement or some sacrifice of economy, especially when the Government has now an opportunity of spending no less than Rs. 70 crores on railway materials. It further recommends a careful investigation at the hands of a special committee as to how far the present quotations for railway wagons from British firms are below their cost of production, and the adoption of anti-dumping measures by Government in the interest of the Indian industry if the recommended inquiry showed that the British tenders represent dumping prices. The other note, signed by Sir Campbell Rhodes, protests against the Stores Department in London arrogating to itself an authority inconsistent with India's freedom of action in the matter of purchases for her own requirements, and demands that purchases for the Government of India must as far as possible be made in India or through agents in India.

It may not be out of place here to state the present position regarding railway industries in India and the purchase of railway stores, as shown in the Railway Administration Report for the year 1921–22. The value of materials purchased by Indian railways in 1921–22 (excluding coal, coke and building materials) amounted to Rs. 38·61 crores, of which about two-thirds are represented by materials of foreign origin. Of the imported total nearly half is represented by the one item, rolling stock, and during the year only about Rs. 1¼ crores were spent in India. Next to rolling stock, the most important head of purchase is the comprehensive one of tools and stores, which represented Rs. 13·34 crores. Of these, Rs. 5·09 crores' worth of articles were manufactured in India. On rails and sleepers, a total sum of Rs. 6·65 crores was spent, 2·82 crores for rails and fastenings and 3·83 on sleepers. Of these, rails and fastenings worth about Rs. 1·19 crores were manufactured in India, mainly due to the enterprise of the Tata Works. As regards sleepers, Rs. 2·65 crores represent the cost of wooden sleepers and Rs. 1·19 crores the cost of metal sleepers. Of the former, those of Indian origin were valued at Rs. 2·35 crores, and of the latter Rs. 42 lakhs' worth were manufactured in India.

A new railway industry enterprise is the Indian Standard Wagon Company, whose works are situated at Asansol, and are designed for an output of 3,000 wagons a year, and include plant for manufacturing from the raw material every item on the wagon except wheels and axles. The works include stamp and press shops, completely fitted with modern powerful machinery, spring shops, smithy and machine shops, &c., all equipped with the latest types of machine tools, fitted with electric overhead travelling cranes and other modern conveniences. At least one firm is known to be erecting works for locomotive manufacture in response to the first tender invited by Government on October 15, 1921.

INDUSTRIAL NOTES.

THE Ministry of Labour state that employment showed a further slight improvement during April. It was good at coal mines, in tinplate and steel sheet manufacture, and fair in the iron and steel, paper, printing and other trades. In many large industries, though employment was still slack, a gradual improvement was reported. The percentage unemployed among members of trade unions from which returns are received was 11·3 at the end of April, as compared with 12·3 at the end of March, and with 17 at the end of April, 1922. The percentage unemployed among workpeople insured under the Unemployment Insurance Acts in Great Britain and Northern Ireland was 10·9 on April 23, as compared with 11·1 on March 26, and 14·4 at the end of April, 1922. The total number of workpeople registered at the Employment Exchanges as unemployed on April 30 in Great Britain and Northern Ireland was approximately 1,261,000, of whom 963,000 were men and 218,000 were women, the remainder being boys and girls. On March 26 the total was 1,289,000, of whom 999,500 were men and 213,500 were women.

In the industries for which statistics are collected by the Labour Department the changes in rates of wages reported as having taken effect in April resulted in an aggregate reduction of over 88,000*l.* in the weekly full-time wages of nearly 700,000 workpeople, and in an increase of 6,500*l.* in the wages of nearly 110,000 workpeople. The principal groups of workpeople affected by reductions were men employed in the merchant shipping service, workpeople in the textile bleaching, dyeing, printing and finishing trades, pottery workers, and men employed in the gas and electricity supply industries. In the merchant shipping service the reductions affecting deck and engine-room ratings amounted to 15*s.* or 20*s.* per month in the case of men on monthly articles, and 5*s.* to 6*s.* 6*d.* per week in the case of men on weekly articles. The cost of living bonuses of workpeople in the textile bleaching, dyeing, &c., trades were reduced by 1*s.* 1*d.* and 7*d.* per week in the case of men and women, respectively, in Lancashire and Scotland, and by 3½ per cent. and 2¾ per cent. on basis rates in the case of time workers and piece workers, respectively, in Yorkshire. The reductions in the pottery industry amounted usually to 10 per cent. on gross wages. Gas workers sustained decreases of ½*d.* per hour or 4*d.* per shift, and men in the electricity supply industry a decrease of ½*d.* per hour in most districts. Among other large bodies of workpeople whose wages were reduced in April were men employed in civil engineering construction, shipbuilders at Belfast, railway wagon builders and repairers, coal tippers at various English ports, tanners and curriers, and men employed in the paint, colour and varnish and the seed crushing industries. Under the Trade Boards Acts there were reductions in the minimum rates fixed for various classes of workpeople employed on stamped or pressed metal wares in Great Britain. The increases in wages mainly affected iron miners in Cleveland and Cumberland, blast-furnacemen in most of the principal districts, puddlers and millmen in the North of England and the Midlands, iron and steel workers in South Wales and Monmouthshire, and steel sheet millmen. During the first four months of 1923 the changes in rates of wages reported to the Department have resulted in a net reduction of 250,000*l.* in the weekly full-time wages of over 2,100,000 workpeople, and in a net increase of nearly 23,000*l.* in the weekly wages of nearly 190,000 workpeople. In the corresponding four months of 1922 there was a net reduction of over 1,900,000*l.* in the weekly wages of 6,800,000 workpeople, and a net increase of about 3,300*l.* in the wages of 22,000 workpeople.

On May 1 the average level of retail prices of all the commodities taken into account in the statistics prepared by the Ministry of Labour (including food, rent, clothing, fuel, light and miscellaneous items) was approximately 70 per cent. above that of July, 1914, as compared with 74 per cent. on March 31. For food alone the corresponding percentages were 62 and 68 respectively.

The number of trade disputes, involving stoppages of work, reported to the Department as beginning in April was 52. In addition, 38 disputes which began before April were in progress at the beginning of the month. The total number of workpeople involved in all disputes in April (including those workpeople thrown out of work at the establishments where the disputes occurred, but not themselves parties to the disputes) was about 110,000, as compared with 83,000 in the previous month and 247,000 in April, 1922. The estimated aggregate duration of all disputes during April was 1,077,000 working days, as compared with 762,000 days in March, 1923, and 5,261,000 days in April, 1922.

It has at last been decided that a third shift shall be worked by the coal tippers and trimmers in the South Wales harbours. For the present, however, the men have agreed to work a third shift for an experimental period of six months, and only so with regard to a third of the tips. Should the state of trade warrant it there might be an extension to a larger proportion of tips.

The sixty-fifth report now issued by the Associated Blacksmiths' and Ironworkers' Society, deals with the railway shopmen, and states that after considerable negotiations with the railway companies' representatives and following failure to reach agreement, the society's claims for the establishment of district rates and conditions of employment were referred to the Industrial Court, whose Award 728, while fixing recognised base rates for the various groups of workmen employed in the railway carriage, wagon, locomotive and civil engineering departments, sets up for the first time in this country the system of grading craftsmen into three classes. This has given rise to considerable dissatisfaction among the workmen, the feeling being that the system will displace the apprenticeship system and thus increase the number of entrants to the trade, with a consequent over-supply of such labour and an inevitable lowering of the standard of living. In a few cases throughout the country attempts were made to place individual members of this society in Grade 2, and these the society in the main successfully resisted; but members, the report adds, must exercise the utmost vigilance at all times in this matter. The secretary adds that the N.U.R., who aspire to represent shopmen, are not averse to such a policy being followed by the railway companies, but the issue rested with the railway shopmen themselves.

In reply to a request formulated by the Federation of British Industries, an official circular has been addressed to county councils, town councils and other local authorities in England and Wales stating that the Government have decided, as regards all works in respect of which grants are given expressly because of unemployment by the Unemployment Grants Committee or by any Government Department, that as a condition of the grant all contracts for, or incidental to, the works are to be placed in this country. The Government also urge in view of present conditions, that the same principle be adopted, in the absence of special circumstances, in the case of all contracts in respect of works carried out by local authorities, whether or not the expenditure on the works is assisted by grants from the National Exchequer or from the Road Fund.

THE CUNARD TWIN-SCREW GEARED TURBINE STEAMER "FRANCONIA."

THE improvement in steamship propulsion and the growth of the demand for comfort in sea travel are well illustrated by the comparison of the latest addition to the Cunard Line, the SS. Franconia, with a vessel of the same name, which was put into commission a little over twelve years ago. The old Franconia was described and illustrated in ENGINEERING, vol. xci, page 246. From that article it may be seen that it had two funnels, two boiler rooms where coal was used as fuel and a large engine room fitted with reciprocating steam engines. The ship had a comparatively short career of useful service and popularity, which was ended in October, 1916, by the action of a German submarine in the Mediterranean Sea.

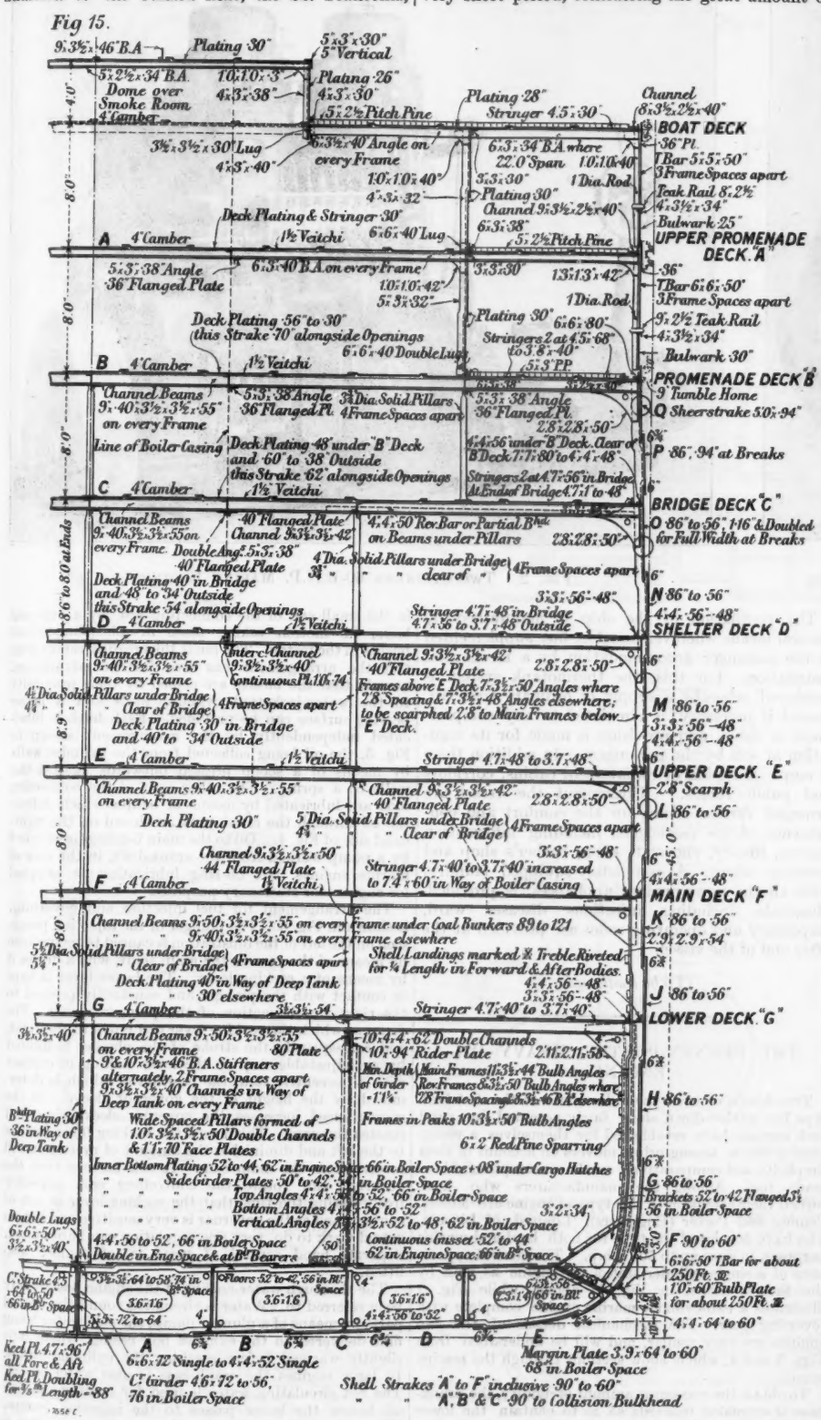
The new Franconia, which was launched on October 21, 1922, by Lady Royden, wife of Sir Thomas Royden, Bart., the chairman of the Cunard Company, has been fitted out in seven months, a very short period, considering the great amount of work involved. In contrast with the old vessel of the same name, the Franconia is a single-funnel vessel with a single boiler-room and a turbine-room of much smaller dimensions than the engine-room of its namesake. The propelling machinery of the new ship consists of two sets of Brown-Curtis compound turbines, driving through double reduction gearing and giving a total ahead power of 12,500 s.h.p., and 70 per cent. of that when running astern. Much of the space which was given over to coal bunkers in the old vessel, has, in the new, been put to other and more popular uses. To the passengers there is a much more evident improvement in the accommodation, the public rooms and other facilities provided for their comfort.

The Franconia was constructed by Messrs. John Brown and Co., Limited, of Clydebank, to designs of the Cunard Steamship Company, Limited. The association of the two companies dates back to the earliest days of both firms, and the Franconia follows on the world-famous ships, the Lusitania and the Aquitania, which were the last vessels built by their combined efforts. The co-operation in the case of the Franconia has resulted in the production of a vessel with many outstanding characteristics. In one respect the ship is unique in that it is the first large vessel to be specially designed and constructed for cruising round the world.

Like the other post-war Cunarders of the largest size, the Franconia is 623 ft. 9 in. long, has a beam of 73 ft. 6 in. and has a depth of 45 ft. The gross tonnage is over 20,000 tons, and the designed speed on service will be 16 knots.

The Franconia is classed 100 A1 at Lloyd's under Special Survey, and meets the requirements of the British and American authorities in all respects as a passenger vessel. The watertight subdivision of the ship has received special consideration and complies with Regulations for the Safety of Life at Sea of the International Convention. All watertight doors fitted in the bulkheads may be operated either by hand or on the Stone hydraulic power system. A double bottom extends fore and aft, the complete length of the vessel, and is used in parts, with deep tanks for the storage of oil fuel. Three holds and 'tween-deck permanent cargo spaces have been arranged forward for the carriage of general cargo, while one of the holds can be used as a deep tank for ballast purposes. In addition to the general cargo spaces aft, two large compartments have been given over to the carriage of refrigerated cargo, the insulation being carried out by the builders. The illustrations on Plate XXXIX show the positions of

Fig 15.


BOAT DECK
UPPER PROMENADE DECK "A"
PROMENADE DECK "B"
BRIDGE DECK "C"
SHELTER DECK "D"
UPPER DECK "E"
MAIN DECK "F"
LOWER DECK "G"
A 4" Camber
B 4" Camber
C 4" Camber
D 4" Camber
E 4" Camber
F 4" Camber
G 4" Camber
Deck Plating & Stringer 30"
1½ Veitchi
Deck Plating 56" to 30"
Deck Plating 48" under "B" Deck and 60" to 38" Outside
Deck Plating 40" in Bridge and 48" to 34" Outside
Deck Plating 30" in Bridge and 40" to 34" Outside
Deck Plating 30"
Deck Plating 40" in Way of Deep Tank
30" elsewhere
Channel Beams 9"×40"×3½"×3½"×55" on every Frame
Line of Boiler Casing
Dome over Smoke Room 4" Camber
Plating 30"
Plating 26"
Plating 28"
Stringer 4.5"×30"
Channel 8"×3½"×2½"×40"
6"×3½"×40" Angle on every Frame
6"×3½"×40" B.A. on every Frame
6"×3½"×40" Lug
6"×6"×40" Lug
6"×6"×40" Double Lugs
6"×3½"×34" B.A. where 22.0" Span
5"×3"×30" 5" Vertical
5"×2½"×34" B.A.
5"×2½" Pitch Pine
5"×3"×38" Angle
36" Flanged Plate
5"×3"×38" Angle
36" Flanged Pl.
3" Dia. Solid Pillars 4 Frame Spaces apart
40" Flanged Plate
Channel 9"×3½"×42"
4" Dia. Solid Pillars under Bridge
Clear of Bridge
4 Frame Spaces apart
Channel 9"×3½"×50"
44" Flanged Plate
5" Dia. Solid Pillars under Bridge
Clear of Bridge
4 Frame Spaces apart
Channel 9"×3½"×42"
40" Flanged Plate
Inter-c Channel 9"×3½"×40" Continuous Pl. 10"×¾
Double Ang.s 5"×3"×38" 40" Flanged Plate
Channel 9"×3½"×42"
4"×4"×50" Rec. Bar or Partial B.ds on Beams under Pillars
Stringer 4.7"×48" in Bridge
4.7"×56" to 3.7"×48" Outside
Stringer 4.7"×48" to 3.7"×48"
Stringer 4.7"×40" to 3.7"×40" increased to 7.4"×60" in Way of Boiler Casing
Stringer 4.7"×40" to 3.7"×40"
Channel Beams 9"×50"×3½"×3½"×55" on every Frame
80 Plate
9"×10"×3½"×46" B.A. Stiffeners alternately 2 Frame Spaces apart
5"×3½"×3½"×40" Channels in Way of Deep Tank on every Frame
Wide Spaced Pillars formed of 10"×3½"×3½"×50" Double Channels & 1¼"×70" Face Plates
Inner Bottom Plating 52" to 44", 62" in Engine Space, 66" in Boiler Space + 08" under Cargo Hatches
Side Girder Plates 50" to 42", 54" in Boiler Space
Top Angles 4"×4"×56" to 52", 66" in Boiler Space
Bottom Angles 4"×4"×56" to 52"
Vertical Angles 3½"×3½"×52" to 48", 62" in Boiler Space
Continuous Gusset 52" to 44", 62" in Engine Space, 66" in Bº Space
Floors 52" to 42", 56" in Bº Space
Channel 9"×3½"×3½"×42"
40" Flanged Plate
Frames above E Deck 7.3½"×50" Angles where 2.8 Spacing & 7.3½"×46 Angles elsewhere; to be scarphed 2.8 to Main Frames below E Deck.
Channel 9"×3½"×3½"×42"
40" Flanged Plate
Shell Landings marked & Treble Riveted for ¼ Length in Forward & After Bodies
10"×4"×4"×62" Double Channels
10"×94" Rider Plate
Frames in Peaks 10"×3½"×50" Bulb Angles
6'2" Red Pine Sparring
Brackets 52" to 42" Flanged 3½" 56" in Boiler Space
Double Lugs 6"×6"×50"
3½"×3½"×40"
Keel Pl. 4.7"×96" all Fore & Aft
Keel Pl. Doubling for ⅜ths Length = 88"
6"×6"×72" Single to 4"×4"×52" Single
C Girder 4.6"×72" to 56" 76 in Boiler Space
Margin Plate 3.9"×64" to 60" 68" in Boiler Space
Shell Strakes "A" to "F" inclusive 90" to 60"
" " "A," "B" & "C" 90" to Collision Bulkhead
Channel 8"×3½"×2½"×40"
6"×3½"×34" B.A. where 22.0" Span
1.0"×10"×40"
3.3"×30"
1 Dia. Rod
Plating 30"
Channel 9"×3½"×2½"×40"
6"×3"×38"
5"×2½" Pitch Pine
3"×3"×30"
1.0"×10"×42"
5"×3"×32"
1 Dia. Rod
Plating 30"
6"×6"×80"
Stringers 2 at 4.5"×68" to 3.8"×40"
5"×3" PP
1.3"×13"×42"
1 Dia. Rod
Plating 30"
6"×6"×80"
Stringers 2 at 4.7"×56" in Bridge At End of Bridge 4.7"×48"
2.8"×2.8"×50"
4"×4"×56" under "B" Deck. Clear of "B" Deck 7.7"×80" to 6"×4"×48"
Stringers 2 at 4.7"×56" in Bridge At End of Bridge 4.7"×48"
2.8"×2.8"×50"
3.3"×56"-48"
4"×4"×56"-48"
2.8" Scarph
2.9"×2.9"×54"
Shell Landings marked & Treble Riveted for ¼ Length in Forward & After Bodies
4.4"×56"-48"
3.3"×56"-48"
Bulwark 25"
Bulwark 30"
9" Tumble Home
Q Sheerstrake 5.0"×94"
P 86"×94" at Breaks
O 86" to 56" 1·16" & Doubled for Full Width at Breaks
N 86" to 56"
4·4"×56"-48"
M 86" to 56"
3·3"×56"-48"
4·4"×56"-48"
L 86" to 56"
K 86" to 56"
J 86" to 56"
H 86" to 56"
G 86" to 56"
F 90" to 60"
6·6"×50" T Bar for about 250 Ft. ℄
1.0"×60" Bulb Plate for about 250 Ft. ℄
4·4"×64" to 60"
Min. Depth of Girder 1·4"
Main Frames 11"×3½"×44" Bulb Angles
Rev. Frames 6·3½"×50" Bulb Angles where 2.8 Frame Spacing & 5·3½"×46 B.A. elsewhere
Main Frames 11"×3½"×44" Bulb Angles
Rev. Frames 11"×4"×56" Bulb Angles
Teak Rail 8"×2½"
4"×3½"×34"
TBar 5"×5"×50"
3 Frame Spaces apart
Teak Rail 8"×2½"
4"×3½"×34"
TBar 6"×6"×50"
3 Frame Spaces apart
5"×2½" Teak Rail
4"×3½"×34"
9" Tumble Home
Q Sheerstrake 5.0"×94"
P 86"×94" at Breaks
O 86" to 56" 1·16" & Doubled for Full Width at Breaks
N 86" to 56"
4·4"×56"-48"
M 86" to 56"
3·3"×56"-48"
4·4"×56"-48"
L 86" to 56"
2·8" Scarph
2·9"×2·9"×54"
K 86" to 56"
J 86" to 56"
H 86" to 56"
G 86" to 56"
Brackets 52" to 42" Flanged 3½" 56" in Boiler Space
F 90" to 60"
6·6"×50" T Bar for about 250 Ft. ℄
1.0"×60" Bulb Plate for about 250 Ft. ℄
4·4"×64" to 60"
Margin Plate 3.9"×64" to 60" 68" in Boiler Space
Shell Strakes "A" to "F" inclusive 90" to 60"
" " "A," "B" & "C" 90" to Collision Bulkhead

LLOYDS NUMERALS & PROPORTIONS.

Breadth Moulded	= 73'6"
Depth Moulded to Shelter Deck	= 45'0
Transverse Number = 73·5 + (45·8)	= 110·5
Longitudinal Number = 600·5 × 110·5	= 66,355
d to "B" Deck = 600·5 ÷ 61·5	= 9·76
d to "C" Deck = 600·5 ÷ 53·5	= 11·22
d to "F" Deck = 45 - (16·75 + 4·5)	= 23·75
d to "G" Deck = 45 - (24·75 + 4·5)	= 15·75

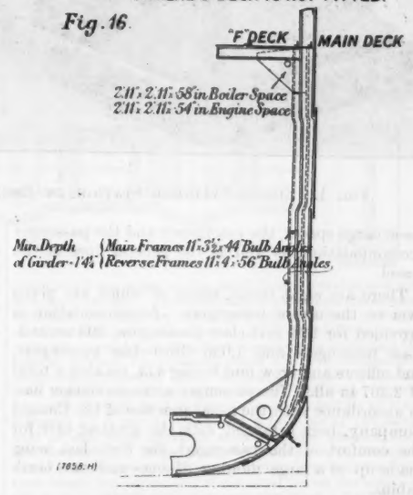
FRAME SPACING.

Frames Spaced 2'0" Apart in Peaks
Frames Spaced 2'3" Apart Forward of 3/5ths Length
Frames Spaced 2'8 Apart Elsewhere

Stem = 1'0" × 3¼" to 1'0" × 2½"
Sternpost = Steel Casting

SECTION SHEWING FRAMING WHERE "G" DECK IS NOT FITTED.

Fig. 16.



HOT-BULB OIL ENGINES FOR LAND AND MARINE USE.

CONSTRUCTED BY MESSRS. PENNEY AND PORTER (ENGINEERS), LIMITED, LINCOLN.

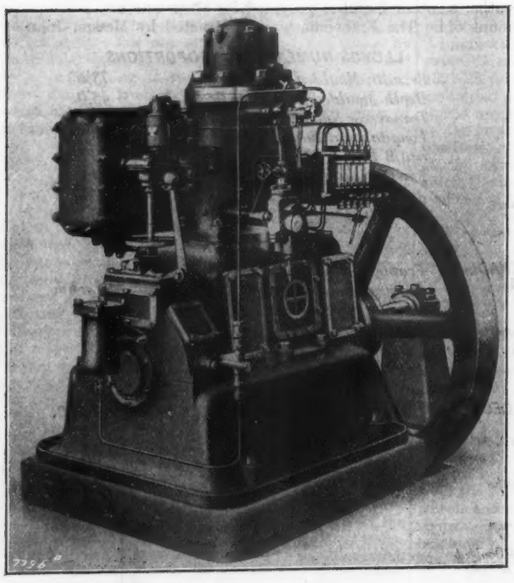


FIG. 1. SINGLE-CYLINDER STATIONARY ENGINE.

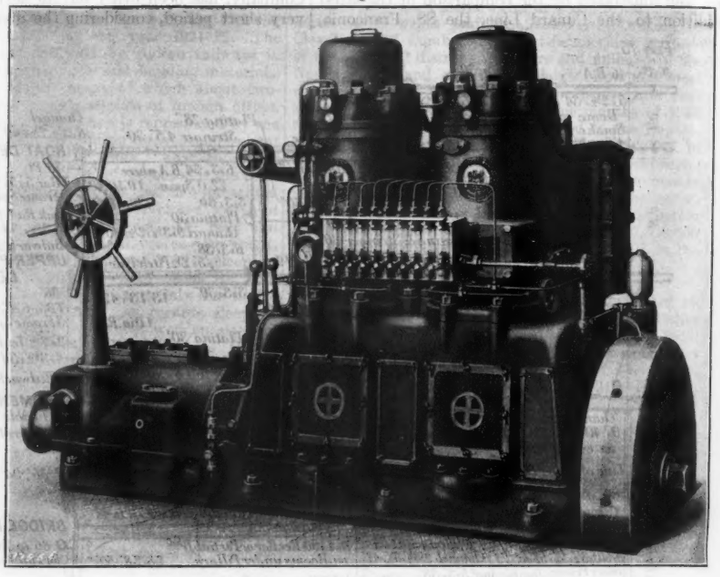


FIG. 2. TWO-CYLINDER 60-B.H.P. MARINE ENGINE.

these cargo spaces, the machinery and the passenger accommodation, as well as the general lines of the vessel.

There are eight decks, seven of which are given over to the use of passengers. Accommodation is provided for 224 first-class passengers, 593 second-class passengers and 1,036 third-class passengers, and officers and crew numbering 414, making a total of 2,267 in all. The passenger accommodation has, in accordance with the usual practice of the Cunard Company, been arranged with the greatest care for the comfort of the passengers, the first-class being made up of a large number of one- and two-berth cabins.

A main staircase with a lift in the centre extends downwards to Deck G and upwards to Deck A, where it emerges into a spacious central hall, from which there are direct approaches to the writing room and card room at the forward end and to the lounge, which is aft of the funnel casing. On either side are garden lounges extending to the ship's side and entered from the main corridors. The smoking room is situated at the after end of this deck. Extensive recreation and promenading spaces have been arranged on this deck, on the boat deck and on Deck B.

The dining saloons, on Deck E, extend to the full width of the ship, and between them is situated the extensive kitchen and galley accommodation. The most modern equipment for service with the greatest despatch is installed in every department. The bakery is fitted with the latest type of dough-mixing machines and with water-tube baking ovens. Vegetable-peeling and slicing machines, dish-washing plant, grills and ranges all reflect the most modern practice. On Deck F extensive public rooms are provided for the third-class passengers. At the foot of the main stairway on Deck G entrance is obtained to the swimming bath, squash racquet court and gymnasium. These are all lofty rooms and extend in height through two decks, necessitating special construction. Ample additional strength has been provided at this part of the vessel to permit their inclusion. Scantlings are shown in the cross-sections, Figs. 15 and 16, on the previous page.

Above the bulkhead deck the ship is divided by firescreen bulkheads as a precaution against fire. In the event of fire in any portion of the ship, the outbreak can be localised by closing the fireproof doors and then dealt with by the efficient fire hydrants, hoses and chemical extinguishers.

The ventilation of the ship is maintained by natural means wherever possible, but supplemented in the passenger accommodation by a mechanical installation. For this, the thermotank system is employed, whereby a supply of ordinary fresh air, heated if necessary, is circulated to any compartment or cabin, and provision is made for its regulation at will by the passengers. In addition there is ample provision of radiators in cabins, corridors and public rooms. Throughout the vessel are arranged various rooms for the comfort and convenience of the passengers, including information bureau, library, chocolate shop, barber's shop and printing offices. A completely-equipped laundry, with all the most modern appliances, is provided. Hospitals, including infectious diseases ward, dispensary and operating room are provided at the after end of the vessel.

(To be continued.)

THE PENNEY-PORTER HEAVY OIL ENGINE.

THE design of two-cycle oil engines of the hot-bulb type has settled down along fairly accepted lines, and such engines have established for themselves a recognised position among prime movers on account of their simplicity and comparatively small consumption of low-grade fuel. Among the manufacturers who have turned their attention to this type of engine are Messrs. Penney and Porter (Engineers), Limited, of Lincoln, who have developed the type for both land and marine purposes, in sizes up to 500 b.h.p. The general appearance of a single-cylinder stationary engine as built by the firm is shown in Fig. 1, above, while Fig. 2 illustrates a two-cylinder marine engine complete with reversing gear. The mechanical details of the two engines are very similar, and will be understood from Figs. 3 and 4, which show sections through the marine engine.

To obtain the maximum amount of rigidity, the crank-case is extended upwards so as to contain the lower ends of the cylinders, a feature which has the further advantage of enabling the crank-case to derive a certain amount of benefit from the cooling water system of the cylinders. The water-jacketting of the cylinders and heads is very thorough, and water also circulates through the exhaust port bars as shown in Fig. 3. This precaution prevents possible trouble from the straining or distortion of these bars by the heat of the exhaust gases, and the consequent risk of trouble with the piston. With regard to the mechanism of the engine itself, it will be noted that the gudgeon pin is held fast in the small end of the connecting rod by a cap and bolts, its motion taking place in phosphor-bronze bushes in the piston. The pin is thus readily removable, and the arrangement has two further advantages, namely that the bushes are cooled by their proximity to the water-jacketted cylinder walls and a larger bearing surface can be provided. Each bush is lubricated independently by the arrangement shown in Fig. 5, the oil being collected from the cylinder walls by means of a scoop pressed outwards against the walls by a spring. The other ends of the connecting rods are lubricated by means of banjos which deliver the oil through the crank-pins, as shown on the right-hand side of Fig. 4. Oil to the main bearings is supplied by a pump worked from the crankshaft, in the case of marine engines, but oil-ring lubrication is adopted for engines for stationary purposes.

The arrangement for fuel injection and governing, is shown in Fig. 6. The plunger of the injection pump, seen on the left of the illustration is caused to reciprocate by means of the cam on the main shaft, which drives it by means of a rocking lever. The latter lever is kept in contact with the plunger and constantly pressed to the right by the action of the plunger spring. The distance which the rocking lever can move to the right, and consequently the stroke of the plunger is limited by an adjustable stop on the lever coming in contact with an eccentric cam, the position of which is determined by the height of the governor sleeve. If the engine speed increases, the governor sleeve rises and rotates the cam. This keeps the rocking lever farther to the left and diminishes the amount of motion it will receive from the main cam. It will be seen that the governor can rotate the controlling cam perfectly freely during the time that the rocking lever is out of contact, and as the governor is very sensitive and has no actual work to do, very fine regulation can be obtained. Separate hand control of speed is, of course, also fitted.

The thorough water-cooling of the engine has already been referred to. Water is circulated round the heated parts by means of a plunger pump, the cold water being first delivered to the exhaust box casing, where it is slightly warmed before reaching the cylinder jacket. In large engines the crank-case is also water-cooled. The hot circulating water is used for heating the fuel oil before the latter passes to the injection pumps. When the engine is fitted with reversing gear, this is of the ordinary epicyclic type as shown in Fig. 4, giving equal speeds ahead and astern. Messrs. Penney and Porter, Limited, provide for direct reversal of the engine by means of compressed air, in four-cylinder engines ranging from 50 b.h.p. upwards, but mechanical reversing gear is fitted, if desired, in sizes between 80 b.h.p. and 200 b.h.p. In the matters of workmanship and attention to detail, the engines we have illustrated will stand comparison with any engines of the type on the market.

HOT-BULB OIL ENGINES FOR LAND AND MARINE USE.

CONSTRUCTED BY MESSRS. PENNEY AND PORTER (ENGINEERS), LIMITED, LINCOLN.

(*For Description, see opposite Page.*)

Fig. 3.

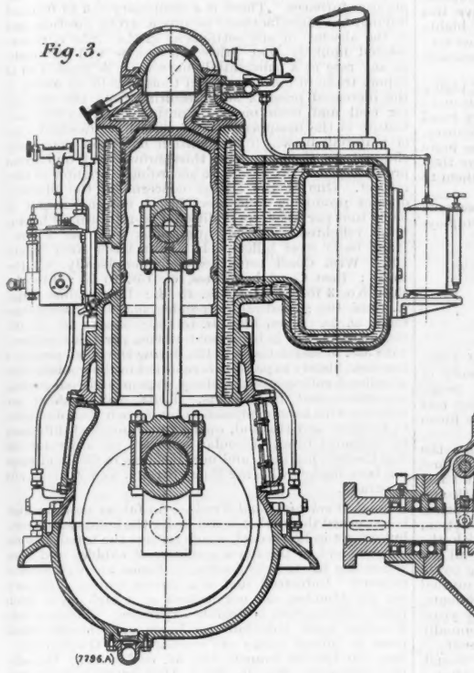


Fig. 4.

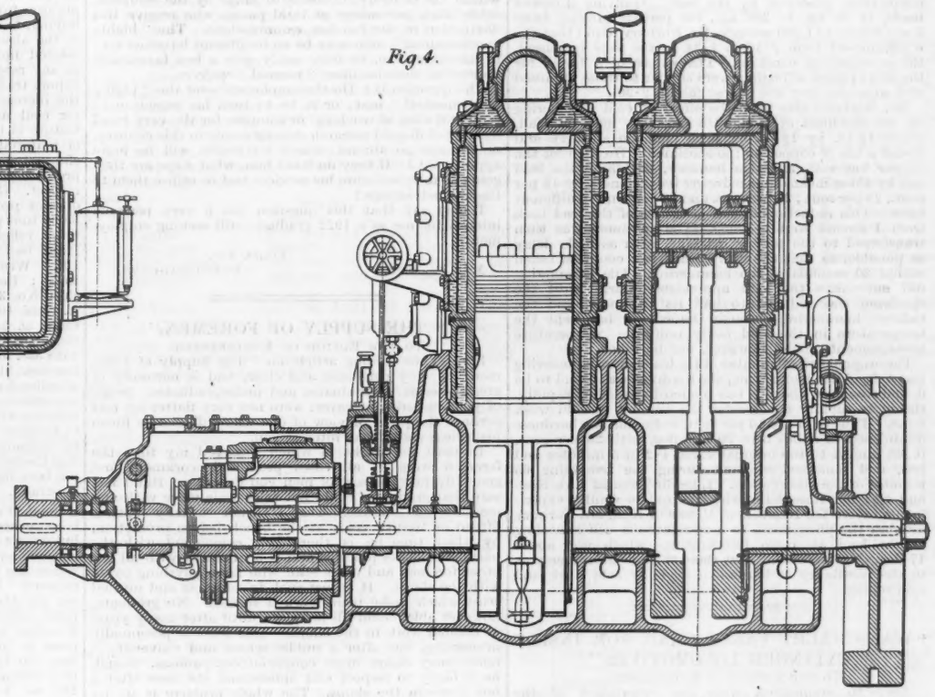


Fig. 5.

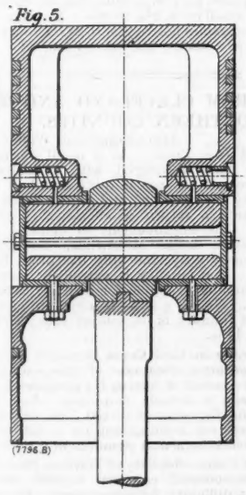
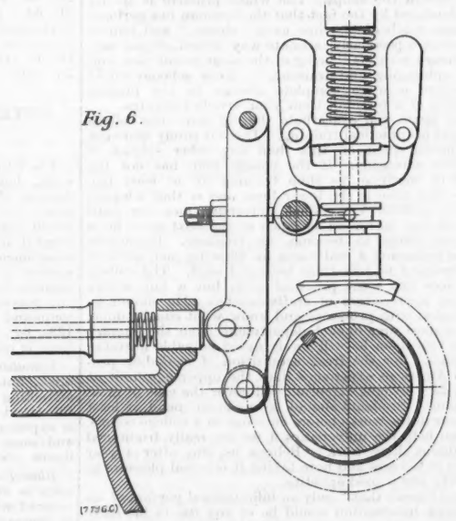


Fig. 6.



ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, 16th inst., at 49, Cromwell-road, South Kensington, Dr. C. Chree, F.R.S., president, in the chair. The following papers were read:—

1. "*The Fluctuations of Annual Rainfall in the British Isles considered Cartographically*," by M. de Carle S. Salter, superintendent, British Rainfall Organisation, and Mr. J. Glasspoole, M.Sc., A.I.C. Maps expressing annual rainfall 1868–1921 as a percentage of the average, fall roughly into three types, indicating respectively (i) excess of orographical rain, (ii) deficiency of orographical rain, (iii) excess of cyclonic rain. Nearly every year of the series exhibits local areas of both excess and defect, the mean range of variation per annum being 35 per cent. with local extremes varying from + 80 per cent. to — 59 per cent. Distant stations show widely different fluctuations, but there is a general resemblance between group values for the west and the east of the country. Local variations are of at least as great magnitude as general variations. In the earlier years the maxima were generally in the east; in the middle of the period in the west; and in the later years in the south. The general rainfall varied from 136 per cent. in 1872 to 77 per cent. in 1887, the deviation exceeding 20 per cent. in only five years, and averaging 8 per cent. From 1868–1882 maxima occurred at intervals of five years; from 1889–1909, of three years; and from 1910–21, of two years. There is also evidence of a long-period fluctuation with two maxima about forty years apart. Annual pressure maps for the same series of years appear to show three main types of variation: (i) Due to shifting of the S.W. wind drift to N. or S.; (ii) due to changes in the gradient; (iii) due to local deflections of the isobars. Type (i) appears to be the principal factor in determining the amount of general rainfall; type (ii) determines the distribution of rainfall; whilst type (iii) affects both variables, and includes all extremely dry or wet years.

2. (*a*) "*An Improved Actinograph*"; (*b*) "*Note on the Influence of a Glass Shade*," by Mr. A. W. Clayden, M.A. Two similar bimetallic coils, like those used for thermographs, but with 7¼ turns each, are mounted about a common axis and attached to a recording pen, in such a manner that the movements of the pen register only the difference of temperature between the two coils. The axis is fixed in a position parallel to the polar axis with the coils at its ends. The instrument stands in a case so that the coil at the lower end is shaded from the sun, while the coil at the upper end is exposed under a hemispherical glass shade to full sunlight and is blackened. The record is written on the usual type of revolving drum, 6 in. in diameter. The result is a trace which records the radiation received by the upper exposed coil in excess of that received by the lower. The areas of the curves were measured by a planimeter in arbitrary units and the results plotted on squared paper for five consecutive years from February, 1914. These curves show a marked and rapid rise of radiation during the four months January to April, a slight drop about the middle of May, followed by a rise to June and a fall during the latter half of the year which is notably more gradual than the vernal rise. The hemispherical shape of the glass shade is chosen so that from whatever direction the sun's rays reach the upper coil there shall be no variation in the way in which they traverse the glass. Samples of daily tracings and of more generalised results were exhibited.

3. "*Notes on the 'Sumatras' of the Malacca Straits*," By Captain E. E. Benest. The author describes the occurrence of these interesting local phenomena and advances a theory as to their cause. These squalls usually blow from the south-west and are more frequent between the months of April and October. A greater number is experienced between Malacca and Pulo Penang than between Malacca and Singapore; but occasionally the latter place is visited and vessels have been driven ashore there owing to a disregard of local warnings. "Sumatras" always occur at night and are generally accompanied by thunder, lightning and torrential rain. The strength of the wind is estimated as lying between 40 m.p.h. and 55 m.p.h. A characteristic cloud formation is always observed, exhibiting a heavy arch or bank of cumulo-nimbus, which rises to an estimated height of upwards of 7,000 ft. and rapidly spreads over the whole heavens. The duration of these "Sumatras" seldom exceeds 2 hours.

HARDNESS AND SPONTANEOUS ANNEALING OF LEAD.

BEFORE the Faraday Society, Mr. A. L. Norbury, M.Sc., of Swansea, described on May 14 an adaptation of a 10-ton Buckton lever testing machine to Brinell testing under conditions when an almost instantaneous application and removal of the load are required. The specimen is placed on a 4-in. table of mild steel, which rests on a steel bar, 6 ft. high, itself attached by a wooden clamp to the body of the machine. On the specimen is placed the Brinell ball, usually 10 mm. in diameter. By means of a jack the beam of the machine is lowered until the 1-in. square steel bar, through which the pressure is to be applied, just rests on the ball; a further quarter turn of the jack then causes the full load to act suddenly for a short period, which is measured by a stop watch. The load is taken off again by means of the jack.

By the adoption of this arrangement, Mr. Norbury has been able to apply loads ranging from 0 up to 300 kg., accurately determined with the aid of a vernier, without interfering with the use of the machine for

tensile testing. The modified machine has been used chiefly for determining the Brinell hardness of lead on which little work had been done. Eugen Meyer made some experiments on lead when publishing his researches on hardness testing in 1908, in which he showed that the strength formula of Rasch and Föppl also holds for Brinell ball tests, viz., $L = a\,d^n$, or $\log L = \log a + n \log d$, where L is the load and d the diameter of the indentation produced by the ball. Applying different loads, of 35 kg. to 200 kg., for periods ranging from 2 seconds up to 1,200 seconds, Mr. Norbury found that the n diminished from 2·33 to 1·94 as the time increased, the a remaining constant. The values of n found for the short period of loading were similar to those obtained with annealed iron and copper (about 2·30).

Mr. Norbury also tried the effect of cold hammering on the hardness of lead. He placed a piece of lead, about 1¼ in. by 1¼ in. by ¾ in. high, on an anvil and rested a bar of copper on the specimen. He then hit the copper bar with a sledge hammer, flattening the lead out by these means and reducing its thickness by 15 per cent., 25 per cent., 30 per cent. and 50 per cent. in different tests. This reduction in the thickness of the lead took from 1 second to 8 seconds. The specimen was then transferred to the testing machine, with as little delay as possible, so that the first Brinell test could be taken within 20 seconds of the hammering. The hammering did not make the lead appreciably warm until the specimen was reduced to half its thickness, and the indirect hammering through the copper bar kept the temperature in the lead fairly uniform; temperature measurements could, however, not be taken.

The original Brinell number of the lead before hammering was 4·2. After hammering, the hardness was found to be 6, and rose even above 7, but the hardness fell off rapidly, the more rapidly the greater the amount of cold work done. Thus with the 10 per cent. reduction the hardness diminished to about 5 in 70 minutes, with 25 per cent. it fell almost to the original value 4·2 in 5 minutes and less, and remained constant during the remaining 65 minutes of the observation. Like Sir Thomas Kirk Rose and also Dr. Rosenhain, who referred to similar experiments before the Institute of Metals in 1912, Mr. Norbury ascribes the phenomena to a spontaneous self-annealing of the lead at room temperature—which was about 17 deg. C. in his case. But there is some controversy as to the possibility of hardening lead by cold work and cold rolling.

"WALSCHAERT VALVE GEAR FOR INSIDE CYLINDER LOCOMOTIVES."

To the Editor of Engineering.

SIR,—In connection with the description of the application of the Walschaert valve gear—arranged externally—to one of the L. M. and S. 4–6–0 inside cylinder engines, which appeared in your issue of the 11th inst., it may be of some interest to point out that this disposition is by no means a new departure in locomotive practice since it has been the custom for many years on the Italian State Railways, where accessibility has been perhaps more sought after than it has here until quite recently, to arrange the Walschaert motion of many inside cylinder engines in this manner. As particular instances the numerous 2–6–0 and 2–8–0 (series 745) engines may be cited. The former class commenced to be placed in service in 1906. In both these designs further simplification has been achieved by locating the steam chests outside the main frames thus dispensing with rocking levers and making a straight line drive possible. Again, in the 4–4–0 two-cylinder compound engines of the Swiss Federal Railways the expansion link drive is derived from a return crank on the crank pins of the driving wheels, but in these machines the combining levers are actuated from the crossheads in the usual manner.

I am, Sir, your obedient servant,

GEO. A. V. RUSSELL, A.M.Inst.C.E.

Sheffield, May 16, 1923.

"DUMMER'S DIARY."

To the Editor of Engineering.

SIR,—With reference to your article of May 4, page 545, on Edward Dummer, of Queen Anne's period, your readers may be interested to know of the existence of a transcript of his diary. This is in the Proceedings of the Royal Artillery Institution, vol. xviii, No. 4, page 105. This article is only indexed under the misleading heading "Pepysian Library," Dummer's name not being used as a sub-heading. Consequently it took me an hour's search round about the date 1890 to trace it.

The original manuscript appears to be in the library of Magdalene College, Cambridge. It is also noticed in Cleaveland's "Notes on the Early History of the Royal Regiment of Artillery," page 104. The transcript was made at the suggestion, I understand, of Sir George Greenhill, who knew of its existence at Cambridge.

I send this note in case the reference may again be lost owing to the faulty index.

Yours faithfully,

J. H. HARDCASTLE (Major).

Woolwich, May 22, 1923.

"THE TRAINING OF ENGINEERS."

To the Editor of Engineering.

SIR,—I was much interested in your leader in your issue of the 18th inst., and especially glad to see your remarks as to the post-college training of the graduate who has had little or no previous practical experience. With regard to your statement that the comparatively few men of outstanding mathematical ability have no difficulty in securing the right kind of employment on leaving college, I cannot say that my experience altogether bears this out. The present are, of course, difficult times in the industry; also, mathematical ability alone is not sufficient; but the point I wish to raise is: How is the employer to detect the man who possesses this outstanding ability? Not even all who can boast of first-class honours come within the category, if one is to judge by the comparatively high percentage of total passes who receive this distinction in the London examinations. The "highly mathematical" man may be an indifferent letter-writer; in interview, too, he may easily give a less favourable impression than his more "normal" *confrère*.

The question is: Do the employers *want* the "highly mathematical" man, or is he to turn his attention to the blind alley of teaching, or compete for the very small number of ill-paid research appointments in this country, or perhaps go abroad, where his merits will be more appreciated? If they do want him, what steps are they going to take to secure his services and to utilise them to the best advantage?

I may say that this question has a very personal interest for me as a 1922 graduate still seeking employment.

Yours, &c.,

May 19, 1923. "POST-GRADUATE."

"THE SUPPLY OF FOREMEN."

To the Editor of Engineering.

SIR,—Your leading article on "The Supply of Foremen" is very pertinent and clear, and is naturally of great interest to graduates and undergraduates. Some of your remarks, however, were not very flattering, and perhaps the point of view of one who will shortly finish his college career may interest you.

In both the works in which I served my time the foremen were in all cases promoted workmen, and generally just the sort of men you describe. But I feel sure that graduates could not take their place with any measure of success. The foreman usually spends fifteen or twenty years at the bench before promotion, by which time he is thoroughly conversant with the particular works practice and is acquainted with all the other foremen and office staff who have anything to do with the shops. It is just such friendliness and mutual trust which make team work a success. No graduate, however able, could fill his place until after many years of manual work in the shops. This work is perennially interesting, but after a public school and university a fellow may desire more congenial companions, though he is likely to respect and understand the men after a few years in the shops. The whole problem is to my mind hindered by the fact that the foreman has perforce to spend much of his time as a "chaser," and handle his men in a peculiarly intimate way, which, as you say, only comes with his "being of the same social class and same upbringing and training." Your scheme would necessitate a more complete change in the present functions of a foreman than your article indicates.

Once again you exacerbate the old sore—the college man and his practical training. There is surely more ink and breath spent on this than any other subject of technical education. If the college man has not the desire to continue his shop training for at least two years—this time is the lower limit and is that adopted by Metropolitan Vickers for university men—or until satisfied that he knows as much as the next man, he is not, nor likely to become, an engineer. Employers do the profession a real harm by allowing men without such training to join their technical staff. The college man does not want practical *skill*, but a fair ability with an appreciation of craftsmanship. He should be acquainted with processes and know what *can* be done. With a short time in each department from the foundry to the tool room he will surely avoid palpable mistakes in design. For the fresh acquisition of workshop processes American experience fixes the upper age limit at about 23; a slight extension will cover the case of most graduates. Students should be made to spend at least one year in the works before entering on a college course. Heaven help the universities if we are really frightened of arduous dirty work! Believe us, Sir, after a year or two of lectures and note taking it is a real pleasure to get dirty and a good appetite.

Your remark that "only an infinitesimal portion of his text-book information would be of any use in his daily duties" would depress me if I thought it were true; even for men with little practical knowledge. My father took two doctor's degrees at college and I know that there is little of this theory which he has not found of some practical application. As William James said: "The occasion and the experience are nothing," it all depends on the capacity for experience, and I know that text books, especially practical text books, do increase this capacity. They are consulted as often in the design office as at college. And why do we read ENGINEERING, the volumes of which are after all a superior sort of text-book?

I am, Sir, &c.,

B. M. T.

THE INSTITUTION OF ENGINEERS, AUSTRALIA.—We have received from this Institution vol. i, 1920, of their Proceedings, giving the names of the council, the rules governing the body, a history of its formation, a list of members, the address by the president, Dr. W. H. Warren, and a series of papers on harbour works, civil engineering and electricity. The book contains about 500 pages and numerous plates. It is published by the Institution, The Royal Society's House, 5, Elizabeth-street, Sydney, N.S.W.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—After a five-days' set-down which allowed ample opportunity for repairs to machinery, the heavy trades resumed to-day under distinctly mixed conditions. Makers of soft steel billets have sufficient orders on their books to guarantee full-time working till the end of June. Similar conditions prevail at the pig-iron furnaces. There is a temporary lull in forward buying, but manufacturers occupy a strong position, and in the absence of any settlement in the Ruhr it is considered unlikely that price concessions will be made, at any rate of a substantial character. A great deal of export trade in machinery and tools is held up owing to the increased price of steel resulting from the demand for coal and coke on the Continent. A satisfactory feature is the disappearance of stocks of standard sizes of material, in which competition has been practically eliminated. Consumers are thus thrown back on current production and prospects are accordingly brighter in that respect. One of the largest concerns in the Sheffield district producing mild steel has a current output of 5,000 tons per week, an additional 60-ton furnace having been relighted. Official quotations rule as follow: Hard basic steel billets, 11*l.*; soft basic steel billets, 10*l.*; West Coast hematites delivered locally, 6*l.* 15*s.* to 7*l.*; East Coast hematites, 6*l.* 15*s.* to 7*l.*; Lincolnshire No. 3 foundry, 5*l.* 10*s.* to 6*l.*; Lincolnshire forge, 5*l.* to 5*l.* 10*s.*; Derbyshire foundry, 5*l.* 10*s.*; Derbyshire forge, 5*l.* 5*s.*; bars, 12*l.* 10*s.* to 13*l.*; sheets, 15*l.* to 16*l.* Basic steel scrap is being sold at 95*s.* per ton compared with 35*s.* in March last and 12*l.* during the boom period of the war. Steady expansion is reported in the manufacture of railway rolling-stock, colliery wagons and coal-cutting apparatus and implements. Twist drill makers are meeting with keen competition by French manufacturers in Belgium and Holland, owing to the marked difference in exchange rates. Circular saws are on order for the Far Eastern markets, and new business in files and rasps has been booked with the Malay Straits, New Zealand and Australia.

South Yorkshire Coal Trade.—As far as new business is concerned the market is still under the holiday influence, but except in house coal, which reflects the usual seasonal change, and in the lower qualities of cobbles and nuts, which are fractionally easier, collieries are well booked forward. Industrial fuel is a strong feature. Exports *via* the Humber are maintained at a high level, while home consumption is steadily expanding. Furnace coke is rather more abundant for home use, though official rates to inland works are unchanged. Quotations:—Best handpicked branch, 32*s.* 6*d.* to 34*s.* 6*d.*; Barnsley best Silkstone, 28*s.* to 30*s.*; Derbyshire best brights, 25*s.* 6*d.* to 27*s.* 6*d.*; Derbyshire best house, 23*s.* to 24*s.* 6*d.*; Derbyshire best large nuts, 20*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 21*s.*; Yorkshire hards, 22*s.* to 24*s.*; Derbyshire hards, 21*s.* to 24*s.*; rough slacks, 12*s.* to 14*s.*; nutty slacks, 10*s.* 6*d.* to 12*s.* 6*d.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—As is usual during Whit week, holidays have interfered with business. Production of Cleveland pig-iron is quite equal to current needs, but stocks are very low, and a little extra buying would soon create a return of shortage. There is a hopeful feeling that improvement in demand will be experienced before long. Meanwhile, however, the market is distinctly easy, the only exception being as regards No. 1. That quality is extremely scarce, and any parcels becoming available for disposal continue to command 130*s.* No. 3 g.m.b. is now no more than 123*s.* 6*d.*, No. 4 foundry is on sale at 120*s.*, and No. 4 forge is quoted 115*s.*

Hematite.—Trade in East Coast hematite is far from brisk, but comparative cheapness of this commodity is attracting a fair amount of buying for purposes for which Cleveland pig-iron is usually employed. No difficulty is experienced in disposing of mixed Nos. at 122*s.* 6*d.*, and some makers are holding out for a rather higher figure. No. 1 hematite is at a premium of a shilling.

Blast-Furnace Coke.—Scarcity of Durham blast-furnace coke is still pronounced, essential supplies not being secured without difficulty by some users. For renewal of contracts with local regular customers the price runs from 44*s.* 6*d.* to 45*s.* delivered.

Foreign Ore.—After a lengthy period of inactivity a few inquiries are once more circulating for imported ore, values of which are a little stronger. Sellers are not now disposed to quote below 25*s.* c.i.f. Tees for best rubio.

Manufactured Iron and Steel.—In finished iron and steel manufacturers have still a good deal of work to execute in completion of contracts, but new orders are few and small, and anxiety to negotiate for business is noticeable. Producers, however, are very reluctant to make price concessions. Cheap Belgian billets have been offering and other Continental competition is rather disquieting, though it is difficult to understand how conditions abroad can permit of foreign firms continuing to undersell in this market. Among the principal market quotations are:—Common iron bars, 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; black sheets, 14*l.* 10*s.*; galvanised corrugated sheets (No. 24 gauge, in bundles), 19*l.* 5*s.*; steel billets (soft), 10*l.*; steel billets (medium), 10*l.* 10*s.*; steel billets (hard), 10*l.* 15*s.*; steel boiler plates, 14*l.*; steel ship, bridge and tank plates, 10*l.* 10*s.*; steel angles, 10*l.*; steel joists, 10*l.*; heavy sections of steel rails, 10*l.* 10*s.*; and fish plates, 14*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has been little change in the state of the steel trade of Scotland since the last report, and a slowing-down is all too evident. Contracts on hand are gradually getting worked off, with very few being booked to ensure continuous running of plant, and the outlook remains rather dark and uncertain. Unless there is a decided improvement in business, the next five or six weeks will see most of the work now on the order books cleared off. Buyers are very reluctant to give out fresh contracts and inquiries are not only for immediate requirements but are not of any great tonnage. Business in ship and boiler plates is gradually getting less, although there is still a moderately good amount of dealing in sectional material. In the black sheet trade the conditions show little change, and while home buyers are not very active the export trade is accounting for quite a fair tonnage. The foreign trade overall is not of very great proportions, and the world's unsettled condition at present is largely to blame for our poor overseas shipments. Prices are being maintained at previous levels and home quotations are as follow:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—In the West of Scotland malleable iron trade a very quiet tone prevails, and there is not much sign of an early improvement. There is a limited amount of work booked which is keeping the wheels running meantime, but new bar iron orders are badly required. The conditions in the steel re-rolling branches are still fairly satisfactory and quite a good output is general. The price for "Crown" bars is steady at 12*l.* 10*s.* per ton, delivered Glasgow.

Scottish Pig-Iron Trade.—The state of things in the Scottish pig-iron trade has varied very little over the week, but is, if anything, a shade easier. The home demand is exceedingly poor and the volume of export trade has recently tailed off considerably. Inquiries both on home and export account are far from reassuring, and the present outlook is not very bright. The following are the current quotations:—Hematite, 6*l.* 7*s.* 6*d.* per ton, delivered at the steel works; foundry iron, No. 1, 6*l.* 1*s.* 3*d.* per ton, and No. 3, 5*l.* 16*s.* 3*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The total shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, May 19, were 1,300 tons, of which 1,022 tons went foreign and 278 tons coastwise. For the corresponding week of last year the totals were 125 tons foreign and 165 tons coastwise, a total shipment of 290 tons.

THE INSTITUTION OF MINING ENGINEERS.—The seventy-ninth general meeting of the Institution of Mining Engineers will be held at Glasgow on June 12 to 14. The programme includes the reading and discussion of papers on the morning of Tuesday, the 12th, and the early part of the afternoon, after which the works of Messrs. Mavor and Coulson, Limited, will be visited. On Tuesday evening there will be a reception by the Lord Provost and magistrates of the city. On Wednesday there will be excursions by special train to visit various collieries, and in the evening the dinner will be held at the Grosvenor Restaurant, Gordon-street. On Thursday, the 14th, there will be a whole-day excursion by steamer on the Clyde. Further particulars may be obtained from the Secretary, 225, City-road, E.C. 1.

BRITISH WATERWORKS ASSOCIATION.—The programme for the annual general meeting of the British Waterworks Association to be held this year at Cardiff, from July 4 to 7, commences with an opening meeting on the afternoon of Wednesday, July 4, at which, after a welcome by the Lord Mayor and the transaction of certain business, the president for the ensuing year will deliver his address. In the evening the annual dinner will be held. Thursday morning will be devoted to the reading and discussion of papers, to be followed by a discussion on the need for revision of legislation on water supply generally. Thursday afternoon will be devoted to visiting local waterworks, and Friday will be spent in inspecting reservoirs, &c., further afield. Saturday will be given up to excursions of a less technical nature to Chepstow, Tintern, Minehead, &c. Complete details of the arrangements may be obtained from the Secretary of the Association, Metropolitan Water Board Offices, 173, Rosebery-avenue, E.C. 1.

STANDARD MOTOR AND AVIATION SPIRIT.—The British Engineering Standards Association, 28, Victoria-street, Westminster, S.W., has recently issued a British Standard Specification (No. 121—1923) for motor and aviation spirit. This specification has been prepared as the result of representations of the Automobile Association and Motor Union, and in addition to Government departments a number of bodies representing users and others have co-operated in its preparation, including the Institution of Automobile Engineers, Commercial Motor Users' Association, Society of Motor Manufacturers and Traders, &c. It is hoped that the specification will be the means of ensuring that a buyer really obtains the quality he is supposed to be purchasing. The tests adopted are those recommended by the Institution of Petroleum Technologists. The specification provides for one grade of motor spirit and two grades of aviation spirit—aviation 720 and aviation 760. In view of possible developments it has been decided to review this specification in six months time, with a view to keeping it abreast with progress. It may be obtained from the secretary at a cost of 1*s.* 2*d.* post free.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—It is practically certain that in July and August the wages of colliery workers in South Wales will be raised to at least 10 per cent. above the minimum of 28 per cent. above the 1915 standard. This assertion is based on an analysis of the returns of the volume and value of the coal trade in April. These show that there was a reduction in the volume of shipments, and in value as compared with March, but that the average price per ton was considerably advanced. The contractions were due to the incidence of the Easter holidays and the fact that there were only 23 working days in April as compared with 27 in March. Shipments in April amounted to 2,474,321 tons, valued at 3,308,313*l.*, as compared with 2,697,788 tons valued at 3,351,965*l.* in March. The average f.o.b. price per ton in April was, however, 26*s.* 9*d.*, compared with 24*s.* 10*d.* in March and 23*s.* 4½*d.* in January. The distribution of trade between the chief ports in the two months is shown below:—

	March.		April.	
	Tons.	£	Tons.	£
Cardiff ...	1,702,190	2,144,399	1,461,617	1,991,710
Newport ...	519,257	652,718	450,876	604,058
Port Talbot ...	225,750	253,914	258,897	321,672
Swansea ...	250,591	300,934	302,931	390,872
Totals ...	2,697,788	3,351,965	2,474,321	3,308,313

It will be seen that notwithstanding the holidays there was an improvement in the volume and value of trade at Port Talbot and Swansea, but a decrease at Cardiff and Newport. The course of prices is shown below:—

Cardiff Steams.

	Small.	Through.	Large.
	s. d.	*s. d.*	*s. d.*
January	16 6	20 0	26 9
February ...	17 8	21 5	27 1
March	18 11	24 6	28 0
April	21 2	25 6	29 10

Swansea Steams.

	Small.	Through.	Large.
	s. d.	*s. d.*	*s. d.*
January	17 0	18 11	26 9
February ...	16 2	18 7	26 5
March	17 11	19 5	25 0
April	19 11	21 6	25 6

Anthracite coals shipped from Swansea in April averaged 37*s.* 5*d.* per ton in the case of large compared with 34*s.* 3*d.* in March, and smalls 22*s.* 7*d.* against 18*s.* 10*d.* Large steam coal exported from South Wales averaged 29*s.* 10*d.* in April compared with 27*s.* 8*d.* in March, and smalls 21*s.* 7*d.* against 19*s.* 2*d.*

The Third Shift.—It has been decided to bring the third shift for coal trimmers and tippers into operation in South Wales on June 4 next, when the hours of working will be from 6 a.m. to 2 p.m., 2 p.m. to 10 p.m., and 10 p.m. to 6 a.m., with half an hour for meals, and from 6 a.m. to 12 noon on Saturday mornings.

Iron and Steel Trade.—Exports of tin plates and terne plates from South Wales last week amounted to 11,939 tons, compared with 10,447 tons in the previous week; black plates and sheets to 7,776 tons, against 6,491 tons; galvanised sheets to 2,672 tons, against 1,362 tons; and other iron and steel goods to 2,904 tons, against 4,414 tons.

ENGINEERING APPOINTMENTS IN THE NAVY.—It has been announced that Engineer-Commander Leslie Robertson, late Squadron-Engineer Officer in the Cardiff, on the staff of Rear Admiral Sir Reginald Tyrwhitt, has been appointed to the Department of the Engineer-in-Chief, taking up his duties on the 16th inst. We also learn that Chief Engineer W. J. W. Bruce, O.B.E., has been granted an honorary commission as engineer-captain of the Royal Naval Reserve. It is interesting to note that Engineer-Captain Bruce is the first engineer to attain this rank since it was instituted some two years ago in connection with the post-war scheme of organisation for the Royal Naval Reserve.

PERSONAL.—We are informed that Messrs. Vickers, Limited, have acquired a substantial interest in the Spearing Boiler Company, Limited, and that the name of the latter company will be changed to Vickers-Spearing Boiler Company, Limited. The directors on the new Board will be: Mr. A. H. Spearing, chairman; Mr. J. Kerr-Bock, of the Spearing Boiler Company, Limited; Mr. Douglas Vickers, chairman of Vickers, Limited; Sir Vincent Caillard, of Vickers, Limited. It is intended that the manufacture of all classes of land boilers will be carried out at the Barrow works of Vickers, Limited.

FOUNDRY SANDS.—As will have been seen from our reports, the Iron and Steel Institute is displaying activity in the matter of moulding sands. *The Iron Age*, New York, states that in late years the sand problem in foundry practice has been much to the front. At Cleveland, Ohio, a few weeks ago, two sessions on sand drew the largest attendance and brought out the liveliest discussions. Proper foundry sand, adds our contemporary, is almost as important as the right metal. In the past, the sand for steel, grey iron and non-ferrous practice has been too often selected by crude methods. The best sands are being exhausted or are becoming more and more expensive. It is vital, therefore, that new sands should measure up to certain scientifically formulated tests and that even synthetic sands should be developed. Just as to-day each melt is carefully compounded and tested, resulting in a better and cheaper metal, so in sand, the application of similar principles will result in better sands, better castings and lower costs.

NOTICES OF MEETINGS.

THE SURVEYORS' INSTITUTION.—Monday, May 28, at 5 p.m., the Annual General Meeting, to receive the Council Report and the announcement of the result of the election of the Council for the ensuing year, will be held in the Lecture Hall. The prizes awarded to the successful candidates in connection with the Preliminary and Professional Examinations will be presented at this meeting.

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS.—Monday, May 28, at 8 p.m., Mr. Delissa Joseph, F.R.I.B.A. will read a paper on "Building Heights and Ancient Lights." Sir William Bull, Bart., P.C., M.P., Sir Tudor Walters and Sir Sydney Skinner, will take part in the discussion which is to follow the reading of the paper at which Mr. Paul Waterhouse, M.A., the president of the Royal Institute of British Architects, will preside.

THE ROYAL SOCIETY OF ARTS.—Wednesday, May 30, at 4.30 p.m.: Ordinary Meeting, "The History and the Development of Children's and Invalids' Carriages," by Mr. Samuel James Sewell. Mr. L. Beresford Seyler, of Messrs. Parker Brothers, will preside. Friday, June 1, at 4.30 p.m., Indian Section, "The Participation of India and Burma in the British Empire Exhibition, 1924," by Mr. Austin Kendall, I.C.S., retired, Secretary, Indian Advisory Committee. Sir Charles Campbell McLeod, Member, Board of the British Empire Exhibition, will preside.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 31, at 6 p.m., Annual General Meeting to receive and consider the Annual Report of the Council, and the Accounts for the year ended December 31, 1922, and to elect Auditors.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday evening, June 1, at 9 p.m., a discourse will be delivered by Professor H. A. Lorentz, Hon. F.R.S., Hon. M.R.I., Haarlem University. The subject is "The Radiation of Light." Afternoon Lectures, at 3 p.m.: Monday, May 28, Sir Walford Davies, Mus.Doc., LL.D., on "Speech Rhythm in Vocal Music" (Lecture II); Tuesday, May 29, Professor W. M. Flinders Petrie, D.C.L., Litt.D., F.R.S., on "Discoveries in Egypt" (Lecture II); Thursday, May 31, Sir William M. Bayliss, LL.D., D.Sc., F.R.S., on "The Nature of Enzyme Action" (Lecture I); Saturday, June 2, Mr. Arthur W. Hill, Sc.D., F.R.S., Director, Royal Botanic Gardens, Kew, on "(1) The Vegetation of the Andes."

THE INSTITUTION OF ELECTRICAL ENGINEERS: WIRELESS SECTION MEETING.—Wednesday, June 6, at 6 p.m. "Wireless Direction-Finding in Steel Ships," by Mr. C. E. Horton.

SAFETY RULES FOR TIN-PLATE WORKERS.—A useful set of safety rules for workers in tin-plate mills has been issued by the Safety Engineering Departments of the National Employers' Mutual General Insurance Association, Limited, of 1 and 2, George-street, Mansion House, London, E.C. 4. The rules are printed in a small booklet of 8 pages, very suitable for distribution among workpeople. Although the rules are particularly intended for tin-plate workers many of them are necessarily of wider application, and all who are interested in the question of the reduction of the numbers of accidents in works are likely to be interested in the booklet. It is priced at 3*d.*

GERMAN IMPORTS INTO NEW SOUTH WALES.—According to a Customs statement forwarded by H.M. Trade Commissioner at Sydney, the value of imports of German origin into New South Wales during the month of February was 19,104*l.*, as compared with 18,003*l.* in January. The principal imports included fertilisers (3,475*l.*), musical instruments, &c. (2,890*l.*), machinery, &c., including cream separators, dynamos, electric fittings, electric heating and cooking appliances, regulating, starting and controlling apparatus, electric appliances, knitting machines, lathes, petrol engines, motive power machinery, paper-working machinery, weighing machines, &c. (1,603*l.*), metals, including wire, trade tools and manufactures of metals (889*l.*), chassis for motor cars (805*l.*), imitation jewellery and clocks (692*l.*), textiles (620*l.*), cutlery (577*l.*), lampware (508*l.*), toys (370*l.*), and leather (363*l.*).

FERRO-SILICON IN BLASTING EXPLOSIVES.—Occasional use has been made of ferro-silicon in the manufacture of blasting explosives during the past few years. It is added as a sensitiser and also serves to increase the specific gravity of the powder. Ferro-silicon is an alloy of silicon and iron of indefinite composition and properties, the proportion of the two components varying widely. It is invariably crystalline in structure, though distinct crystallisation is absent in alloys containing 50 per cent. or over of silicon. The exact number of distinct silicon-iron compounds is in dispute, the number mentioned ranging from two to five. The proportion of impurities in ferro-silicon is largely dependent upon amount of the impurities present in the raw materials from which it is manufactured. It is made commercially either in the blast furnace or the high-temperature electric furnace. That prepared by the first method contains 20 per cent. or less of silicon, the richer alloys being made by the second method. In the blast-furnace method the charge consists of iron oxide, siliceous iron ore, and coke, the reduction being effected by the carbon. In the electric-furnace method two kinds of charges may be used. These may be either wrought iron, steel, or cast-iron, turnings, quartz, or sand, and charcoal, coke, or coal or a charge of siliceous iron ore, quartz, or sand, and charcoal. Iron turnings are generally preferable to ore.

COAL-CUTTING MACHINES.

CONSTRUCTED BY MESSRS. MAVOR AND COULSON, LIMITED, ENGINEERS, GLASGOW.

(*For Description, see Page* 648.)

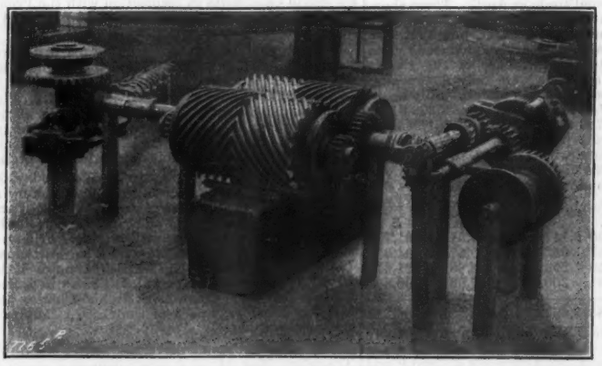


Fig. 19. Air Turbine Rotors with Haulage Gear.

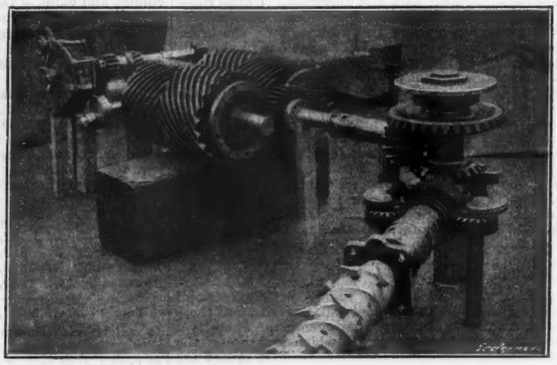


Fig. 20. Drive from Air Turbine Rotors to Cutter Bar.

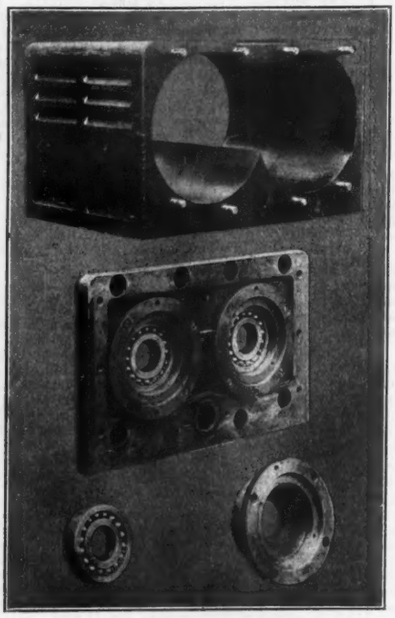


Fig. 21. Cylinders, Cylinder Head and Rotor Bearings for Air Turbines.

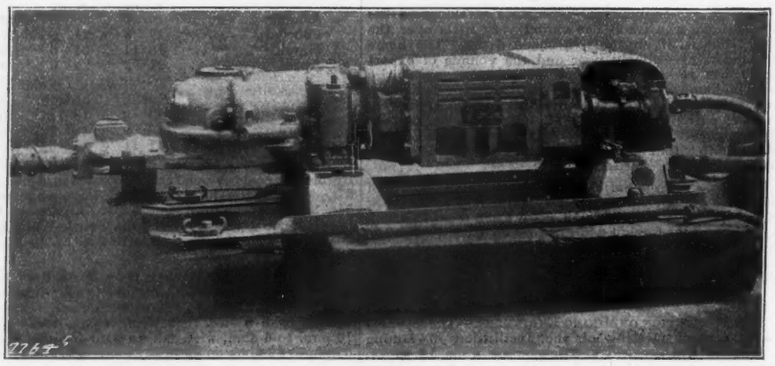


Fig. 22. Air Turbine Coal-Cutter.

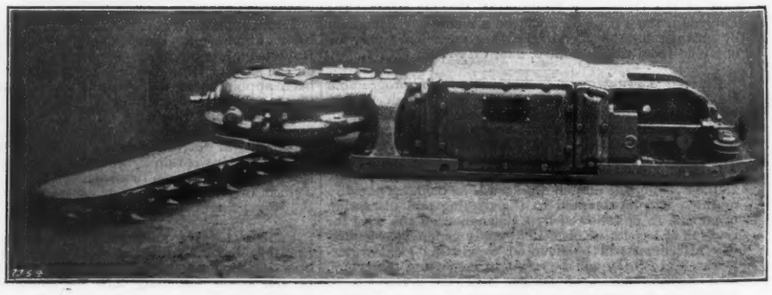


Fig. 24. Chain Type of Coal-Cutter.

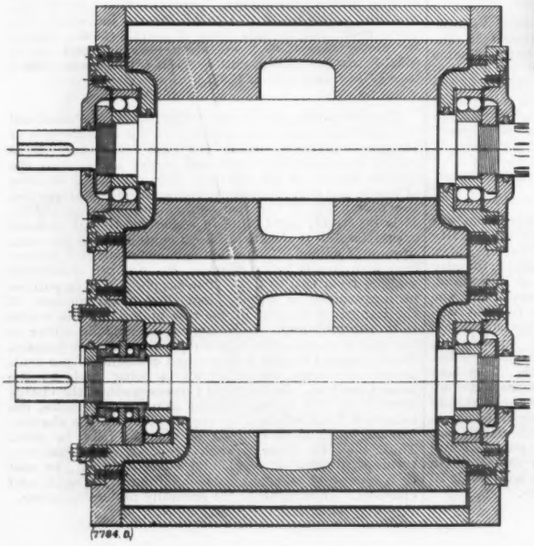


Fig. 23. Section through Air Turbine.

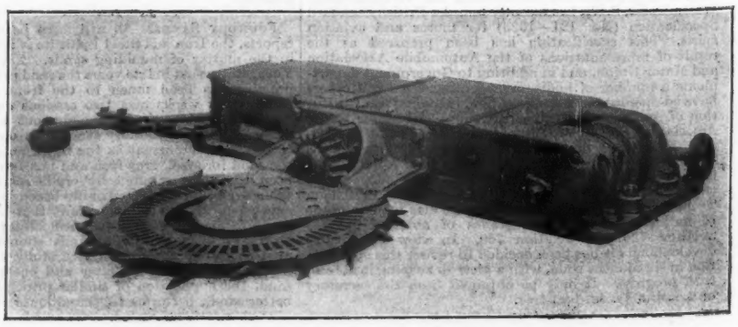


Fig. 25. Disc Coal-Cutter.

ENGINEERING MAY 25 1928

Fig. 9. "C" DECK.

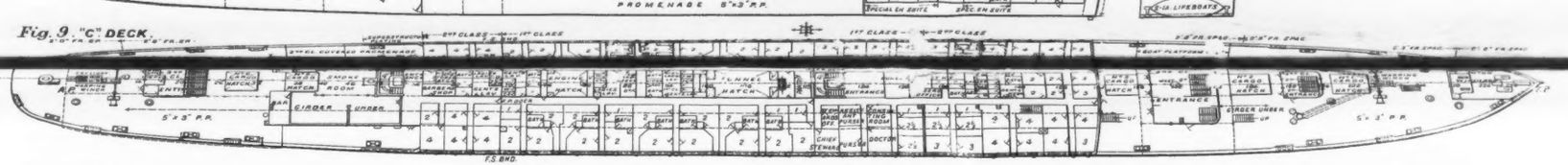


Fig. 10. "D" DECK.

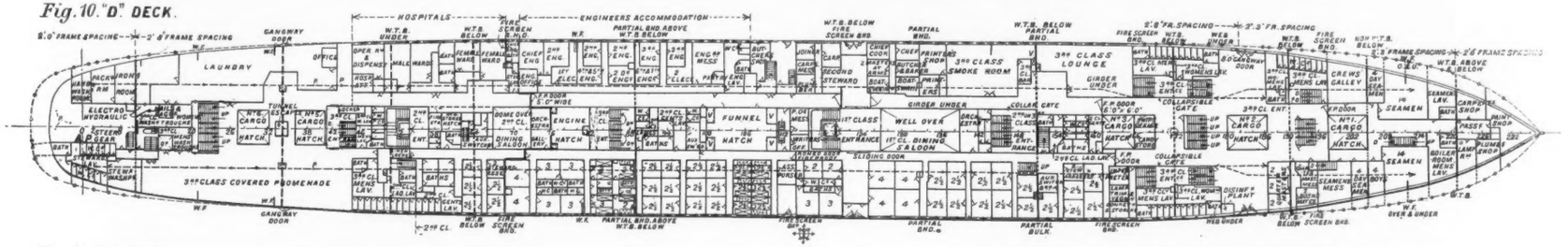


Fig. 11. "E" DECK

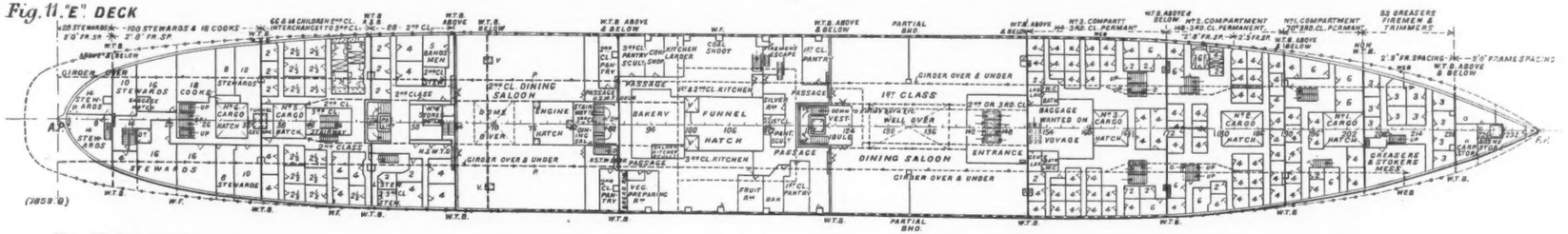


Fig. 12. "F" DECK.

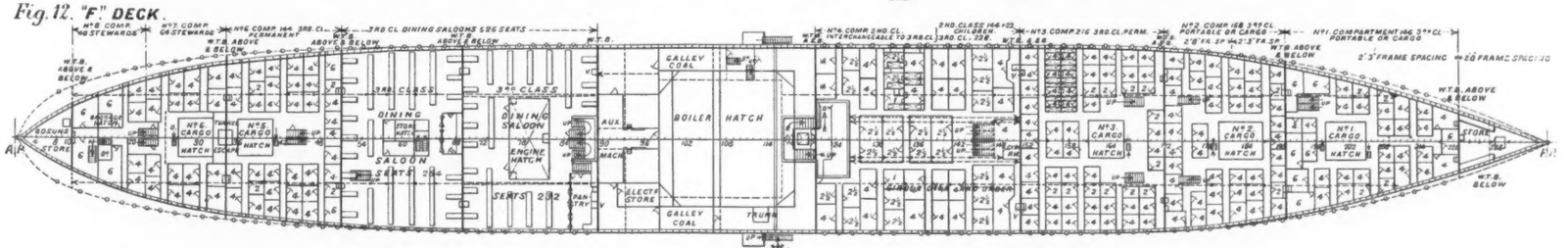


Fig. 13. "G" DECK.

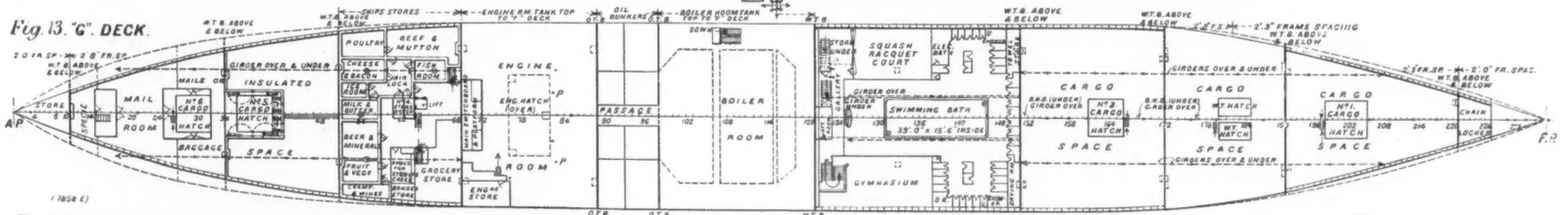
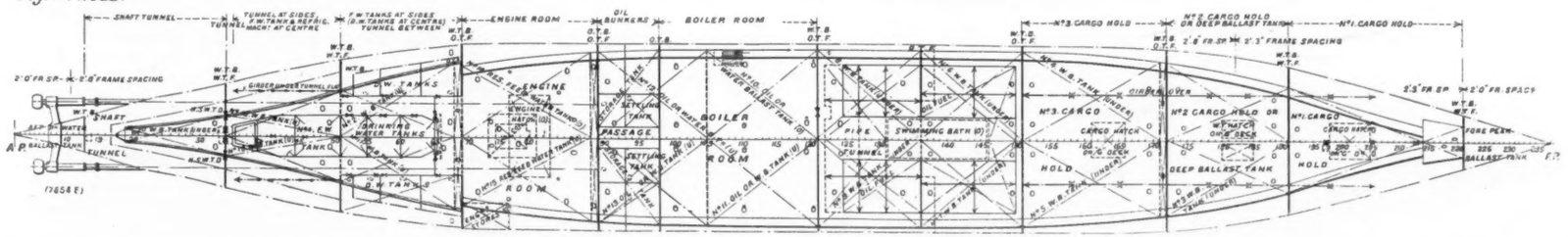


Fig. 14. HOLD.



THE CUNARD TWIN-SCREW GEARED-TURBINE STEAMER "FRANCONIA."

CONSTRUCTED BY MESSRS. JOHN BROWN AND CO., LIMITED, ENGINEERS AND SHIPBUILDERS, CLYDEBANK.

(*For Description, see Page 651.*)

Fig. 1. RIGGING PLAN.

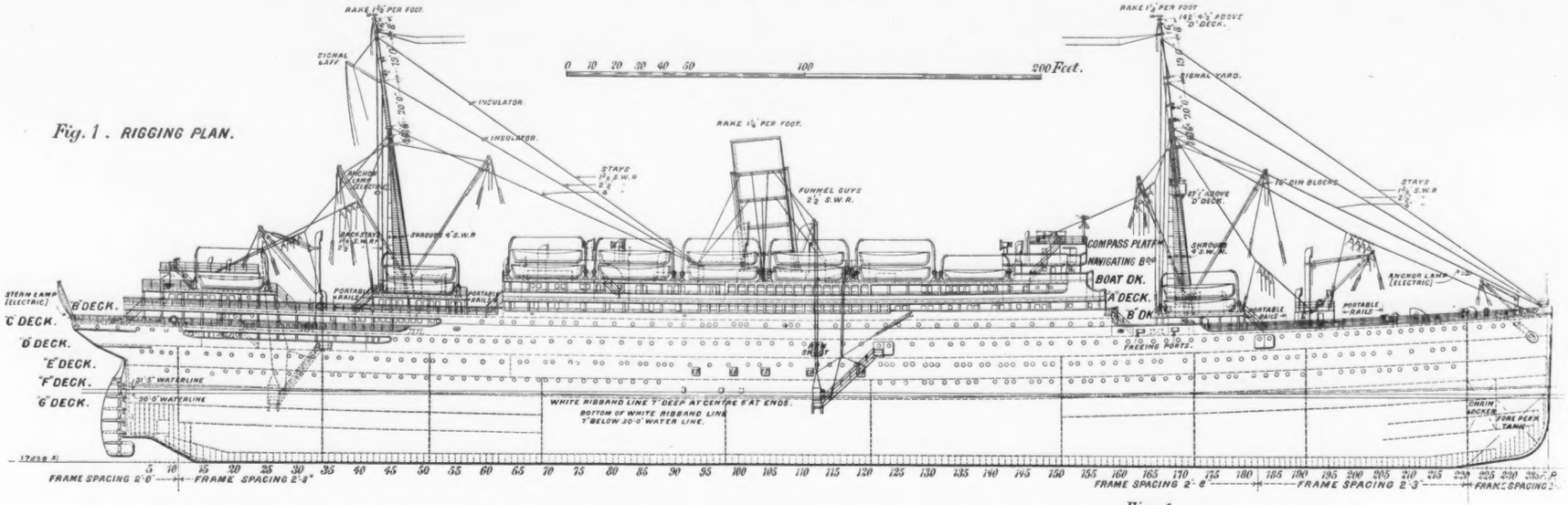


Fig. 2. DOCKING BRIDGE.

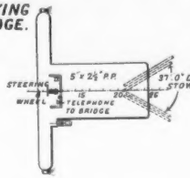


Fig. 3 BOAT DECK.

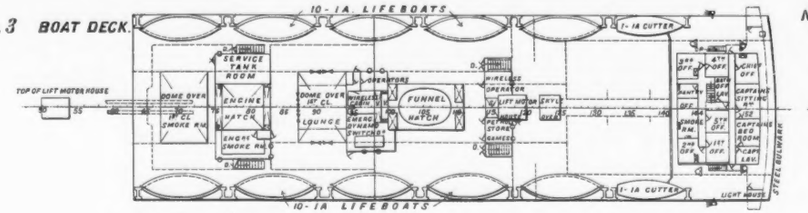


Fig. 4. NAVIGATING BRIDGE

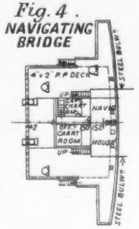


Fig. 5. STANDARD COMPASS PLATFORM

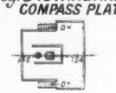


Fig. 6. BOAT PLATFORMS AFT.

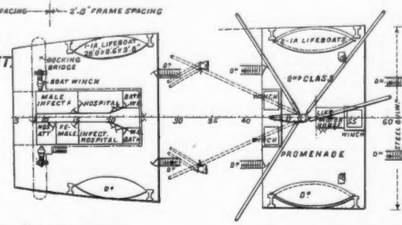


Fig. 7. "A" DECK.

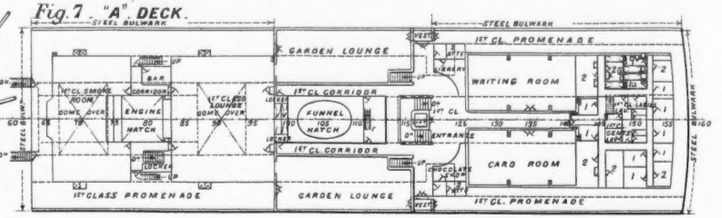


Fig. 8. "B" DECK.

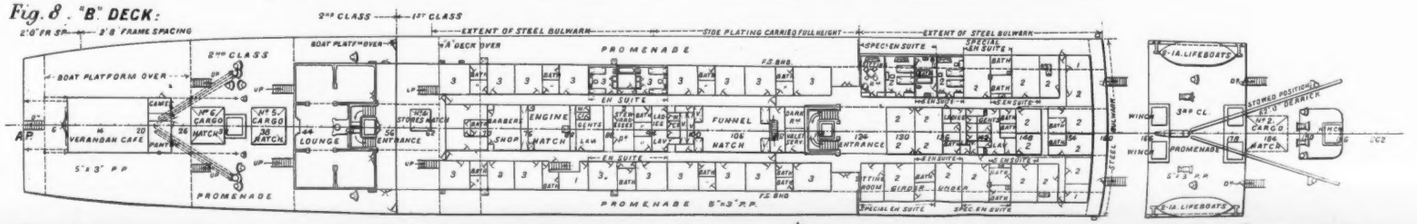
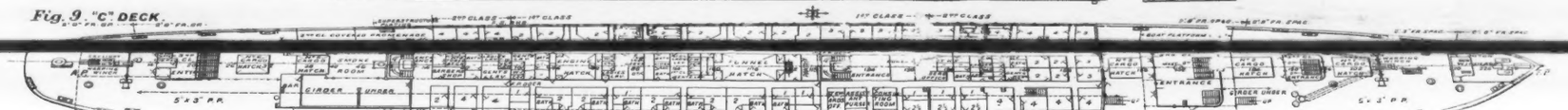


Fig. 9. "C" DECK.



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Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand, London, W.C.2.

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TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8598 GERRARD.

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"ENGINEERING" may be ordered from any newsagent in town and country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance :—

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UNITED STATES: For subscription, New York; W. H. Wiley 432, Fourth Avenue. For Advertisements: J. S. Allan 30, Church-street, New York.

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Two-Page Plate.—THE CUNARD TWIN-SCREW GEARED TURBINE STEAMER "FRANCONIA."

ENGINEERING.

FRIDAY, MAY 25, 1923.

THE PROVISION OF LIFEBOATS.

A VERY competent authority has maintained that no lesson was to be learnt from the Titanic disaster, which, it will be remembered, arose from a remarkable series of coincidences which can hardly recur again. The night was a wonderful one, calm and moonless, the sea dead smooth, and the berg with which the collision occurred had recently capsized and was thus dark instead of glistening white. After the collision the ship remained on an even keel, and did not founder for 2 hours. The boat provision was far from sufficient to accommodate the whole of the passengers and crew, yet although there was no lack of discipline, these boats left filled only to two-thirds of their capacity. Nevertheless the inadequacy of the accommodation impressed the popular imagination more strongly than did the extraordinary safety of the Atlantic passenger services as demonstrated by the record of the preceding twenty years during which these ships had made some 32,000 passages, marked by only 25 accidents causing loss of ship or loss of life. In these 25 accidents 68 passengers and 80 of the crews were killed. Not merely was this record remarkable, but analysis of the figures showed that it was being steadily improved year by year. The governing idea both of the shipowner and of the Board of Trade was that the ship was in herself the best lifeboat, and attention had been concentrated on improving the seaworthiness of the liner rather than in providing alternative means of escape which there was every reason to believe would prove effective only in conditions little likely to be realised in service.

From the standpoint of pure logic, there can be but little doubt that no change should have been brought about by the Titanic catastrophe. No insurance company would, in fact, have quoted a lower rate on the life of passengers crossing the Atlantic on a liner carrying boat accommodation for all than for one less fully provided. Human activities are however, never wholly controlled by pure logic, and concession has to be made to emotion as well as to reason. Hence, the disaster, led to the promulgation of new rules, according to which every foreign-going passenger vessel was required (if long enough) to carry lifeboats sufficient to accommodate all on board. If the length of the vessel was insufficient to enable davits to be fitted to carry this number of lifeboats, then the ship was required to carry additional lifeboats and rafts to make up the shortage. These additional boats or rafts might, it was provided, be grouped under the davits in tiers or fitted one within the other, or they could alternatively be arranged in rows across a deck, bridge or poop. The whole of the boats and rafts were required to be heavy sea-going craft, and consequently weighed on the average about 2 tons each. It was recognised throughout that in heavy weather most of this additional accommodation would be useless, that is to say in the very conditions in which they would normally be required.

These rules were promulgated in May, 1914, and owing to the callous inhumanity of the Hun there were many occasions during the war, in which it was possible to test the value of the provision under very much more favourable conditions, than were likely to arise in times of peace. Many of the ships sunk by torpedoes were sunk in calm weather and smooth seas, and the experience thus gained has shown that it was not merely in rough weather that the additional provision made was of little or no value. This is the more noteworthy since under war conditions passengers willingly accepted discipline which they would otherwise have resented, whilst both officers and crews were more on the alert. Boats were kept constantly swung out, and the running gear was kept under close supervision.

The experience thus gained is reviewed in a recent report* of the Merchant Shipping Advisory Committee, who came to the conclusion that some very important modifications are required in the above rules. Out of 131 casualties boats sufficient for all were carried in 101 cases, whilst in the remaining 30 part of the accommodation was dependent on boats or rafts carried in tiers under the davits or across the deck. The committee report that an analysis of the experience thus gained shows that even in smooth water conditions the accommodation provided cannot be made use of in the time available. In the first place it commonly takes some 5 minutes to take the way off the ship, and in some cases the ship sunk in less time than this.

The Empress of Ireland, which was accidently rammed by the Storstad, sank in 15 minutes, although subdivided by 10 transverse bulkheads, and the Lusitania, subdivided by 11 principal bulkheads and a longitudinal bulkhead each side along the coal bunkers, sank in 20 minutes, whilst under the most favourable conditions as to discipline it is held that it would take 30 minutes to 45 minutes to get away 2,000 persons in 40 boats. In heavy weather the time would increase by between 50 per cent. and 100 per cent., whilst if the vessel took a list it would be impossible to make use of all the boats. In this connection the committee report that it takes 16 minutes to get into boats the whole crew of a battleship numbering 1,000 highly trained and well-disciplined men.

If the maximum use is to be made of the boats, the committee state that the rule as to "women and children first" must be abandoned. It is, however, very unlikely that this consideration will affect practice in the British mercantile marine, where the captain and officers will prefer to maintain this high tradition, even at the expense of some additional loss of life. Since in most cases a list of the vessel to one side or the other is to be expected, it is impossible to allot passengers beforehand to particular boats, and in no case can they be practised in what to them is the formidable operation of getting from the ship into the boats and being lowered to the sea. Taking all factors into consideration, the committee conclude that not more than 15 minutes can be counted on for the launching of the boats, and this being so, only those boats already swung out can be relied upon, and in some cases

* Report on Life-saving Appliances, Training and Organisation. H.M. Stationery Office. Price 3*s.* 6*d.* net.

the additional boats and rafts required by the rules have seriously impeded the launching of these. It is not in all cases or in all services possible to carry the boats swung out, or on chocks at the ship's side, which do not involve lifting the boat in launching. Where, however, this is practicable the committee state that much time can be saved. The committee hold that in any case these heavy seagoing lifeboats attached to davits should be looked upon as the first line of protection, and that davits should as far as practicable be carried along the full length of the ship on both sides, up to the number necessary to provide boat accommodation for all. As an additional resource light rafts are recommended, particularly in view of the fact that "wireless" provides a means of calling for assistance from other vessels, and hence on frequented routes, there is less necessity than formerly to contemplate voyages in boats or rafts over hundreds of miles of sea. In these circumstances the first need is to keep the sinking ship afloat as long as possible, and secondly to keep alive those who have been forced to abandon her. At times, a few minutes may suffice, whilst at the worst on frequented routes a limited number of hours should bring rescue.

In this connection some interesting experiments have been made by Dr. Leonard Hill, F.R.S., and Dr. Argyle Campbell, who have found that even wet clothing affords the body great protection as compared with nakedness, and the addition of a light mackintosh or oilskin makes a further great reduction in the loss of heat. It is recommended, therefore, that provision of light oilskin suits for men and women should be provided as part of the stores on rafts. These rafts, which form the "additional provision" where it is impracticable to provide readily-available lifeboat accommodation for all, form the subject of a report by a subcommittee, who state that the present form of heavy raft cannot be handled satisfactorily without mechanical appliances and should accordingly not be included in the life-saving equipment as a substitute for boats. Lighter forms, which can be thrown overboard or floated off when the ship sinks are, however, recommended for use on foreign-going passenger ships. These rafts are not designed to support the whole weight of persons in the water, the buoyancy provided for being 32 lb. per person.

The present practice seems to be to provide boats for all passengers and crew, but of the total only a fraction is carried attached to the davits, and the remainder would accordingly be available only under very exceptionally favourable conditions. The Majestic, of 56,500 gross tonnage, for example, may carry a total of 4,124 passengers and crew, and 62 boats are provided, of which 36 are attached to davits. The Aquitania, with a gross tonnage of 45,600, may carry 4,186 passengers and crew, for whose safety 74 boats are provided but only 27 are carried on davits. The Kaisar-i-Hind, of 11,430 gross tonnage, is certified for 919 passengers and crew. The boats provided number 20, of which 18 are on davits. The Canada, of 9,540 tons gross, is certified for 1,645 passengers and crew, and carries 33 boats capable of accommodating 1,658, but of these only 14, capable of holding 682, are on davits.

In summarising their conclusions the committee emphatically reaffirm the position that the ship herself is the best lifeboat of all, and that provision against possible disaster must be subordinated to the assurance of the stability and seaworthiness of the vessel herself. Heavy seagoing lifeboats should be provided in so far as they can be carried actually on davits, and in cases where more than 15 and less than 20 such boats are provided, 2 should be motor boats fitted with "wireless" and searchlights. If only one motor boat is carried it ought to be able to be launched from either side. All vessels carrying more than 10 boats should be required to have one at least fitted with wireless if they do not carry a motor boat. At sea the boats should be carried swung out or arranged on chocks in such a way as not to require lifting in launching.

Even in cases where the boats thus provided for are capable of accommodating all on board, the committee hold that further equipment in the shape of light rafts should be furnished with capacity sufficient for the support of one-fourth of the total number of persons on board. This recommendation is based on the consideration that it may be impossible to use all the heavy boats owing to the vessel taking a heavy list. Where it is impracticable to provide sufficient boats for all on davits, only such additional boats should be carried as can be stowed without impeding the prompt handling of the other boats and the rafts. If it is practicable to provide, with this restriction, boat accommodation for all on board, a further supply of light rafts is required.

The essential quality in these rafts is stated to be handiness, the weight and size being such that they can be handled without mechanical appliances. The latter may be provided for launching the heavy boats, but this provision must be looked on merely as a convenience, it being essential in the opinion of the committee that it shall be possible to launch these boats by man-handling in the shortest possible time.

ROAD IRONWORK.

DURING the last Session of Parliament Capt. Bagley asked the Minister of Transport whether he was aware that many hundreds of different types of road ironwork details were in use throughout the country, most of which served exactly the same purpose, and whether, in view of the large sums of public money then—and now—being expended on roadways, he was prepared, on grounds of economy, to recommend some system of relative standardisation of ironwork for the various classes of roads. The reply given was, in effect, that no action was considered advisable. No doubt it was thought that the issues at stake would scarcely justify the expense of setting in motion the ponderous machinery of a departmental inquiry. Yet the subject opens up a wide field of thought in these days for municipal engineers and surveyors. So far as the Metropolitan area is concerned, some preliminary steps have already been taken in this direction, and a small committee of borough engineers has been set up to collect data. The whole matter is, of course, specially prominent at present, when so many public authorities are giving out their annual or biennial contracts for ironwork, amongst other supplies.

Where road surfacing materials in general are concerned the circumstances of each case are governed by a wide variety of local conditions, but, where definite mechanical structures are required, each for an almost invariable purpose, it is surely absurd that so great a variety of types and designs should be indefinitely perpetuated up and down the country. Many of these types are certainly better than others and not a few, perhaps, are really bad.

The principal details of road ironwork are manhole and lamphole covers and frames, and gully gratings and frames. It will be agreed that these three items have been in use in some shape or form, perhaps in their present shape if not form, for anything from 50 to 100 years, in fact, just as long, we might say, as foul and storm water sewers have been laid beneath road surfaces. Only recently, however, since the advent of fast-moving and heavy vehicular traffic, has the design of road ironwork again attracted the urgent attention of the expert roadmaker.

Take first the case of the manhole cover and frame. Ready access to the sewer is essential. Therefore the clear opening within the frame must be sufficiently large to comfortably admit the bulk of a man's body, often heavily clad. Whatever the dimension, it should at least be one where a standard might suitably be arrived at, having regard to the possibility of hurried exits to avoid the effects of sewer gas. At the same time weight is a consideration, for, although the greater the diameter the greater the weight, excess of weight—which does not always mean added strength—should be avoided. The cover requires to be readily lifted out of the frame, so that economy of weight compatible with strength of design must be aimed at. Grit, dirt and tar often bind the two together, so that when the keyholes, similarly plugged, have been cleaned out and hand power has failed to move the cover, special lifting tackle has to be brought into use—a contingency for which preventive measures should be taken in working out the ideal design. The cover should fit well inside the frame, as too free a movement sets up still worse trouble. Freedom of movement generally means "rock" and is due not so much to loose fit as to uneven seating. The "clank-clonk" of a manhole cover as lorries, cars or cycles pass over it, besides being an annoyance, is a real source of danger. Cases are on record of covers being tipped up by the wheels of quick moving vehicles and drawn right up out of their frame and literally thrown into the roadway, leaving the gaping manhole exposed. Further, constant movement of the cover on the frame seating sets up a grinding action, and this, in the course of time, wears down the bearings so that the top of the cover lies well below the rim of the frame into which it is supposed to fit evenly. Various designs, patented or otherwise, to obviate this rather common fault of "rocking" have been put on the market, but no data as to results are available from official sources. Again, it is desirable that a manhole frame should provide a good key or bond with the road surface, thereby avoiding depressions being worn in the immediately adjacent material of which the road happens to be made. Another important point is that the upper surface of the cover should be non-slipping and, as such, durable. The best method of achieving this end, by means of raised studs, deep chequers, or depressed slots, are matters of varying individual experience. Lamphole covers and frames, of course, in spite of their smaller diameter, are in much the same category as manhole covers and frames.

Gully grates and frames, we may safely assume, are primarily designed to remove water, liquid mud, &c., from our roads as quickly as possible. For this reason the gratings must bear some definite relation, as regards openings, to the rush of water that can reach them over the effective area they serve, to the capacity of the gully they shield, and to the size of the outlet pipe which connects the gully with the sewer. The grating bars, therefore, whilst far enough apart to answer their purpose in this respect, and not choke up, must yet be near enough to prevent an undue quantity of paper, rubbish, sweepings, &c., from finding their way into the gully pot—no easy problem to satisfy, apart from the greater issues of the road gradients, absorptivity of the road material, and rainfall of the district. The weight of traffic using the road should, of course, decide the strength of the gully grate, though occasional abnormal traffic is always apt to upset any calculations of this kind. Broken gully grates are common enough, yet it is questionable how far the tendency to increase the weight of cast-iron gratings is justified on the score of cost and convenience in handling, even in the case of roads along which heavy traffic is continuously passing. Cast iron is always liable to hidden flaws, and where cast iron must be used, the scientific distribution of the metal is more important than mere weight and makes most for the ultimate strength of the grating. Gully grates have to be lifted more frequently than manhole covers, so the question of weight in their case has an added significance. This point may, no doubt, be partly met by the use of hinged gully grates, though the chief reason for providing hinges is just as much to prevent removal from their frames by mischievous persons as to facilitate lifting. Many engineers, however, will only use the "drop-in" type of grating. There should be no difficulty in fixing a minimum clear opening within the frame so that cleansing scoops can be properly handled. Yet, here again, calculations may be upset by the more general use of vacuum cleaners—luxuries at present denied to many municipal councils.

The "flat" and the "dished" types of gully grates have their own adherents, but the suitability of both, each for its separate purpose, would seem quite capable of definition on standard lines.

Some engineers favour the use of cast-iron gully pots in preference to the more common earthenware type. It may be held that the latter are more convenient where road grading is liable to alteration, as a bed of cement, or a brick cushion beneath the cast-iron gully frame can readily be raised or lowered to the level required. The best types of cast-iron pots, are, as a rule, designed so as to provide

an independent water seal when the gully is cleaned out, and so as to allow the solids to be retained in the pot whilst the water runs away. When the common type of earthenware pot is cleaned out, the seal or trap remains inoperative until the next rain storm comes along, unless, of course, the pot is at once filled up with clean water, a custom which is often more honoured in the breach than in the observance.

With regard to "rocking" gully grates, very much the same reasons apply as in the case of manhole covers. The inequalities of two rough cast-iron surfaces bearing together with almost inevitable "hard spots" in the metal obviously do not make for permanent stability. A continuous stream of traffic passing over, combined with accumulations of dirt and grit, wet and dry, sooner or later sets up the fatal "rock." It is highly desirable in consequence to produce a cast-iron gully grate which will effectually overcome this disadvantage.

The cost of road ironwork, it must be acknowledged, bears but very small relation to the entire cost of a modern roadway. Hence the matter of ironwork is well worth stressing, for, if money can solve all difficulties, very slight additional outlay would be initially demanded. Road engineers in these days of urgent economy and State aid, are, of course, often compelled to sacrifice finished design in important details of this sort to excessive respect for the ratepayers' pocket and to a very wholesome fear of rigorous governmental audit.

TURBINE DISASTER IN THE UNITED STATES.

To the list of disasters which have occurred with large impulse turbines in the United States must now be added the total destruction of a 10,000 kw. machine at the Mill-street station of the Indianapolis Light and Heat Company, particulars of which are given in our contemporary, *Power*, of May 15. The machine in question, which had been in service since 1916, ran at a speed of 1,800 r.p.m. Early in the morning of April 2, as the machine was about to be put on load, it completely wrecked itself. The flying pieces of metal smashed the oil pipes of a 15,000 kw. unit which was running at the time and so put this out of action, they damaged the blading of another 15,000 kw. set which was opened up for repairs, and they broke a 12-in. steam pipe and knocked over the 50-ton accumulator and smashed the step-bearing pumps of a 5,000 kw. vertical unit which was kept as a standby. Thus every machine in the station was put out of action, a total of 45,000 kw. of plant being shut down and the supply of electricity completely stopped. At the time of the accident the machine which burst had been warming up for over an hour, with the rotor in motion, the generator fields had been excited, and a man was at the stop-valve presumably in readiness for the machine to be paralleled in on to the bars. This man and the only other man who was in the turbine room at the time, were both injured, but fortunately nobody was killed.

The cause of the accident, like that of many similar ones, does not appear to be definitely known. The circumstances seem to have been almost identical with those when a 5,000 kw. 3,600 rev. machine of the same type burst at Regina two or three years ago, and as in this case the completeness of the disaster seems to have destroyed the evidence of the cause. The shaft was bent and broken, and the coupling weighing about 1,500 lb. flew over the top of the vertical unit and struck the overhead crane. Several of the turbine discs had pieces broken out of them and it was hardly possible to decide which part failed first. If overspeeding was the cause, it is difficult to see how this could have occurred with a man at the stop-valve waiting for the machine to be paralleled. Under such conditions the machine would be under his close observation, and in any case the safety-trip should have acted. He would, moreover, be very unlikely to be deliberately overspeeding to test the safety trip, at a time when he was about to put the machine on load.

While the immediate lessons of the disaster are those to be learnt by the designers and constructors of the machine, the consequences of the occurrence are of great importance to all engineers concerned with the layout of power stations. In commenting a few weeks ago on a paper read before the Institution of Electrical Engineers on the driving of power-station auxiliaries, we referred to the inadvisability of the boiler-feeding arrangements being dependent in any way upon the operation of electrical plant, and the accident at Indianapolis entirely justifies our contention. At the time of the accident motor-driven boiler-feed pumps were in use, and similar pumps also supplied the water to the feed-heater. As soon as the rush of steam through the broken main was stopped, the boilers, of course, commenced blowing off, and the electrical feed pumps being naturally useless, the water-level in the boilers became dangerously low. The reserve steam feed-pumps were started, but the steam pipe to the reserve steam-driven cold-water pump having been broken by the accident, the water in the heater could not be renewed.

To increase the difficulties of the situation, the fires on the large chain-grate and underfeed stokers could not be damped with the rapidity desirable under the circumstances, these grates being presumably motor driven, although this is not stated. In view of the stoppage of the feed supply it was imperative to get rid of the fires in some way, and as for some reason the city water service was not available to quench them the fire department had to be called in, with chemical extinguishers we again presume. While this was going on, temporary electrical connections were made between the bus-bars and the feeders of another plant in the city. This allowed the electrically-driven pumps to be re-started, within 50 minutes of the breakdown, and within another hour the boiler-plant was once more under control, and steam could be supplied to the 15,000 kw. set, the oil pipes of which had meanwhile been repaired, and the oil tanks refilled. No material injury had been done to the boilers, which work at 235 lbs. per square inch, by the shortage of water, the only damage which occurred being apparently the breakage of a superheater support.

Owing to the drenching of everything in the turbine room with steam, it was not considered advisable to put the 15,000 kw. repaired machine on the line for several hours, but within less than nine hours from the time of the accident it was carrying load. Two days later the 5,000 vertical unit was again in commission, and in another two days the other 15,000 kw. set was on the line. The way in which the situation was handled from start to finish appears to have been highly creditable to all concerned, but the real lessons of the event seem to be directed to those who doubt the necessity of providing that the safety of a large boiler-house shall be entirely independent of the action of the main generating plant.

THE TRADE AND PROGRESS OF BELGIUM.

THE Belgian people, in old times, never lacked courage, initiative and perseverence, and the work already accomplished in reconstruction bears ample testimony to the persistence of those attributes. Work is being energetically pushed forward in the repair of the damage caused by the war and the millions devoted to that work are a heavy load on the State and the taxpayers. New taxation has been imposed and a great endeavour has resulted in economies in administration. We are enabled to see the progress made from time to time, by the periodical publication of the valuable trade reports of our Department of Overseas Trade. A recently-issued one, containing much of interest, deals with the Economic and Financial Conditions in Belgium up to December, 1922, and was prepared by Mr. J. Picton Bagge, Commercial Secretary to His Majesty's Embassy at Brussels.

The Public Debt amounted to 35,743 million francs by the end of September, 1922, an increase in twelve months of 1,806 million francs. Even with the increases in direct and indirect taxation, the General Budget for 1923 shows an estimated deficit of 2,325 million francs.

During the period covered by the report there were signs of great improvements in industrial activities, marked by the reduction of unemployment to figures less than those of normal pre-war times. Increased efforts to re-establish trade are a healthy sign of the determination of Belgium eventually to reach the goal of prosperity. There are, of course, many obstacles to be overcome before any great step forward can be recorded. Among them the settlement of the Reparations question and the improvement of the franc exchange are the most outstanding. The exchange problem, owing to international matters in large measure independent of the will of the Belgians, is one of great complication. This, however, can be said in favour of the Belgian Government, that it has not had recourse to the printing press despite the enormous demands on the public purse.

The welfare of any people is bound up with the prosperity of its industries, and while efforts are being made by the Government and by the enterprise of private firms and individuals to promote the sale of Belgian products abroad, the attempts to increase production are being intensified. The application of the Eight-Hour Bill has reduced output, and demands are being made to amend the measure to allow greater flexibility in working and so enable Belgium to trade on fair terms in the world's markets. As the agricultural production of Belgium is insufficient for the needs of her population, importation of foodstuffs is required to the extent annually of $2\frac{1}{2}$ milliard francs. With the franc depreciated to its present value, this importation has the effect of keeping up the cost of living. Belgian finance has always played a large part in the development of tramways, electric power schemes, mining ventures, engineering, chemical and other works in all parts of the world, and the return from these investments forms a valuable item among the invisible factors in its international balance sheet.

Foodstuffs and vegetable products are exported from the various parts of the British Empire to Belgium and form an important part of that country's imports. Among the classes of material of international trade, which are more closely associated with engineering, are fuels, metals and machinery. Of the total coal imported during the first nine months of 1922, Britain supplied one-third, but a much smaller proportion of the coke, a field in which Germany stood supreme. During the year a shortage of coke was experienced, and in consequence the price of Belgian pig-iron remained high. In spite of that, the number of blast furnaces in activity was doubled and at the end of the year, two-thirds of the normal number in use in pre-war days were in operation. Germany received a large proportion of the total exports of steel blooms and flat bars. Large quantities of steel rails were supplied during 1922 to the Argentine, Finland, Japan and other countries, the total export amounting to 100,000 tons. This total would have been very much greater but for the restrictive effects of customs tariffs. Sheet iron to the extent of 99,000 tons was shipped during the year, principally to France, India, Japan and Spain. Other varieties of steel bars and plates to the total of 442,000 tons were supplied to Germany, India, Great Britain, the Argentine, Spain, Japan and Egypt. In the field of export of constructional steel British competition is severe.

An important contract for railway rolling stock for China worth 150,000,000 francs has improved the situation in that section of activity. During 1922 work in electrical construction, refrigerating and brewing machinery was plentiful, while some good home orders were given for sugar factory plant. Of the 7,625 motor cars imported into Belgium in the first nine months of last year only 40 were obtained from Britain, but nearly one-third of the 2,268 imported motor cycles were British machines. Belgian cars, to the number of 188, were exported to Britain in the same period.

Not only were exhibitions and fairs held to promote Belgian trade, but a National Propaganda Committee for Foreign Trade was established under the patronage of the Government, for the purpose of co-ordinating all the various activities. Trade missions went to South America and resulted in the establishment of committees at Santiago for the purpose of furthering the relations of Belgium and

Chile and at Lima to improve Belgo-Peruvian trade. A similar mission went to Japan in February of this year. The British Chamber of Commerce in Brussels was established in 1898 to facilitate trade between the two countries.

Among the new activities the development of the Campine Coal Basin is of great importance. Already the output has reached 1,300 tons a day, and this will be increased to 6,000 tons in about two years' time, when it is expected that the whole of the projected works will be in operation. Railway communications with the district are being improved, and the preliminary work in the Liege-Antwerp Canal is being actively pursued. This waterway will have its origin in the Meuse, near Vise, and will reach the coalfield at Genck. Other connecting canals are under construction, and the older waterways are being enlarged to allow of the passage of barges of 2,000 tons capacity.

In the province of Antwerp it is proposed to extend the electric power supply by the erection of high-tension lines radiating from the stations. It is proposed that the installation should be entrusted to concessionary companies. The total cost is estimated at 100,000,000 francs. Similar schemes are under consideration for six other provinces. Proposals for electrifying the suburban railways are being discussed, but the main line scheme between Brussels and Antwerp has been postponed until financial conditions improve. An automatic telephone system was inaugurated in one of the Brussels districts in November. Other sections are to be converted in turn, but it will be two or three years before the whole system has been made automatic. A new company, Société Belge Radio Electrique, in which the British Marconi concern have an interest, has been formed to deal with all matters connected with wireless telegraphy and telephony.

Important new port works were begun in Antwerp during the year, and the Government is erecting new works in connection with the improvement of the Ghent-Terneuzen Ship Canal. The new port of Brussels and the ship canal were formally opened by King Albert in November last. This canal connects Brussels with the River Rupel and so with the Scheldt. It has a total length of 18½ miles and will permit of the passage of vessels of 340 ft. length, 45 ft. beam and 19 ft. draught. The difference between the levels at Brussels and of the Rupel is dealt with by two intermediate locks at Capelle au-Bois and Willebroeck.

THE ORIGINS OF THE CONCEPTION OF ISOTOPES.

FORTY years ago the atomic theory was apparently based upon an indivisible and immutable atom. The atomic theory still rules, but the immutable atom is gone. The old theory recognised that the metallic iron need not resemble the ores from which it was isolated, nor the compounds into which it passes; the essential point was that the atomic mass remained unaffected in all the changes. It was strange though, that, whilst the iron metals have nearly the same atomic weight, chlorine and bromine, also distinctly members of a family, differ widely as to mass, and that the atoms of oxygen and nitrogen again, though quite dissimilar in properties, stand near one another as to mass. These remarkable periodicities in properties, and particularly also the multiplicity of the spectra of one and the same element, forced scientists more and more back to the old belief that all atoms must be built up of some smaller constituents. Then came the discoveries of the existence of such constituents (electrons) and of radioactivity; atomic mass seemed to become subordinate to atomic number, and gradually the indivisible elementary atom grew into a complex planetary system. A chemist, whom fate had kept absolutely secluded for some decades and then released again, might slowly be converted to acceptance of most of these modern theories. But isotopes—distinct elements, chemically indistinguishable and inseparable, though frequently of different mass? How that heresy could become orthodox doctrine was exposed by Professor F. Soddy, F.R.S., of Oxford, the originator of the term isotopes, in his Royal Institution discourse of May 4, on "The Origins of the Conception of Isotopes."

The word isotopes means "the same place" and is to indicate that distinct elements may occupy the same place in the periodical table. Analytical studies had given the chemists 92 elements and had left a few vacant places in the table, some of which spectroscopic discoveries have filled up. Radioactivity placed new methods of investigation at the disposal of physical chemists, far more delicate than spectroscopy. The elements uranium and thorium were found to disintegrate under expulsion of α, β and γ rays, into successive products, stable for many years or for seconds, and 34 elements were gradually discovered for which there was no room in the periodic table. The old "properties of existence," as Professor Soddy called them, had to be distinguished from the radioactive properties characteristic of the explosion terminating the existence of the element as such. But the earlier radiochemistry did not afford a hint of isotopes. As a chemical element radium, the first radioactive element recognised, was indeed quite normal, and there was a vacant place for it in the periodic table as a higher member of the barium family. The theory of atomic disintegration was founded upon the original observation, made by Rutherford and Soddy in 1903, that thorium, Th, is continuously producing a new substance, ThX, separable from Th by precipitation with ammonia; ThX itself passed into an emanation (thoron) and further into a solid. Extracting in 1905 radium from a Ceylon mineral, thorianite, Ramsay and Hahn discovered radiothorium, RaTh, which proved the direct parent of ThX. But chemists all over the world failed in chemically separating RaTh from Th, and the matter seemed inexplicable until Hahn found, in 1908, a further intermediate product, mesothorium. The final series (with the life periods inserted) was: Thorium (2×10^{10} years), mesothorium I (9·67 years), mesothorium II (8·9 hours), radiothorium (2·91 years), thorium X (5·25 days), &c.; the first and fourth, and again the second and fifth of these products are isotopes. The radiothorium which Ramsay and Hahn had obtained from thorianite, was not the radiothorium in the mineral, but that subsequently produced from the easily-separated mesothorium after it had been removed from the thorium. The lapse of time was the essential point; with immediate frictionation of the radium-meso-thorium-barium mixture, they could not have discovered radiothorium; they could do so after giving the product time to accumulate.

Professor Soddy elucidated the relations by means of a string of balls. Different colours distinguished the chemically-separable products; the isotopes were originally of the same colour, but they would change their colours in the course of time. If RaTh had been the direct product of Th, the two might yet remain unseparated; the separation of the products depends upon their being alternative rather than successive in the series. Successive products only have the same character when the change does not involve expulsion of charged particles. To make separation possible, the life periods must be favourable, and because they are not in the case of uranium, the separation of U I and U II, upon which Professor Soddy spent years, looks hopeless, whilst the just-mentioned thorium separation is effected commercially. It had been believed that uranium X passed into ionium; but the series is: U I (6×10^9 years), UX_1 (35 days), UX_2 (1·6 minutes), U II (3×10^6 years), ionium (10^5 years), radium (2,440 years), &c. Thus, though two short-lived products intervene between U I and U II, as in the thorium series, this time difference (days against millions of years) is hopelessly unfavourable, and the life periods of the UX and ionium (also isotopes) are equally discouraging.

Further manifold researches by Fleck, in Professor Soddy's laboratory, and others, left little doubt as to the chemical identity of isotopes. No difference was traced even in the spectra of ionium and thorium (likewise isotopes) which Auer von Welsbach isolated from 30 tons of pitchblende, radium D proved to be identical with lead, and the number of isotopes increased. Then early in 1913, the periodical law of radioactive evolution was, after a preliminary enunciation by Hevesy and A. S. Russell, generalised almost simultaneously by Fajans in Karlsruhe and by Professor Soddy in the statement, that every α-ray expelled causes a shift in the periodic table by two places in the direction of decreasing mass, and the expulsion of one β particle a shift of one place in the opposite direction. That implied that chemical character had nothing to do with radioactivity, nor with the radioactive series to which the element belongs, nor its atomic mass. Room was made for many isotopes, and the ultimate products of both the radioactive disintegration series should be isotopes of lead. The latter conclusion was confirmed; uranium gave a lead of mass 206, thorium a lead of mass 207·9, ordinary lead having the mass 207·2.

Since the α-particle carries two positive charges and the β one negative charge, successive elements in the periodic table should differ by unit charge. That fitted into the nuclear theory of the atom, put forward, tentatively first, by Rutherford in 1911. In the nucleus the positive charge is concentrated; but the nucleus also contains negative electrons, and the nuclear charge is the algebraic sum of the two and might be the same in cases when the positive charges and the negative charges counted singly are not the same. Transmutational changes of α and β rays are sharply distinguished from the numerous processes during which electrons are detached from the shell of the atom. Those detachments are concerned in chemical change, frictional electrification and thermoionic and photoelectric processes. The particles of radioactive change come from the nucleus, and isotopes have the same nuclear charge. The effect on the chemical character produced by the expulsion of one α particle is exactly undone by the effect of the expulsion of two β particles; the product becomes isotopic with the parent. For the members of this system the electronic shell would be identical; hence the chemical and spectroscopic identity. The radioactive changes, being nuclear, are irreversible. The shell electrons which determine almost all the atomic properties, except mass and radioactivity, Professor Soddy remarked in concluding, are "the bureaucratic instruments of the nuclear government. It is only when the atomic or social system breaks down that we learn even of the existence of the internal constitution."

INVENTORS AND THE CROWN.

IN connection with certain important matters recently the relationship between an inventor and the Crown, particularly as it affects the public at large, has arisen and it might be of interest to consider the legal aspect of this relationship under ordinary circumstances. Inventions are commonly protected by Letters Patent. The law governing the matter is really a statute law based on the common law.

Prior to the passing of the Statute of Monopolies in 1623 the Crown had a common law right under which it granted Letters Patent, but owing to the abuse of this the statute declared all monopolies illegal with the exception of those covering any new manner of manufacture. No new right was thereby given to the Crown, but the old right for that comparatively small field was permitted to be retained. Modern Patent Law is based on the Statute of Monopolies, the present Acts in force being those of 1907 and 1919. These are consolidated, but no official publication of the consolidated Act is available.

Section 29 of the Act of 1907 and the corresponding section of the Act of 1919 now replacing it provides that a patent shall have to all intents the like effect against His Majesty the King as it has against a subject. Provisions are made that any Government Department may use the invention for the services of the Crown on payment which may be settled in a particular way. Before April, 1920, the Treasury Department had the power to settle these terms, but since that date the matter may be referred to the Court. At the present time, although any Government Department may by themselves or their agents exercise the invention for the services of the Crown, authority to the agents may no longer be orally given or implied but must be specific and in writing, so that if an agent acts

without this written authority he is not protected from infringement proceedings by the patentee.

The latest Act includes a paragraph which is also important in view of research made by Government Departments, that where an invention which is the subject of any patent has before the date of the patent been duly recorded in a document by or tried by or on behalf of any Government Department (such invention not having been communicated directly or indirectly by the applicant for the patent), any Government Department or its agents authorised in writing may use the invention so recorded free of any royalty notwithstanding the existence of the patent.

Although the patent operates against the Crown as against any other party, the Patent Acts do not provide any steps for enforcing the rights of a patentee against the Crown. If a contract comes into question a petition of right can be brought and the matter is ultimately tried in the King's Bench. It is therefore customary for any Government Department concerned to nominate a defendant who can be sued for the purpose of testing the matter of infringement in Court. It is quite possible that in future Acts this matter will be made clear, because it is inconsistent to bind the Crown in one way and yet give no means for enforcing the law.

Occasionally a Government Department joins with an inventor in protecting an invention. In the case of such joint applicants, apart from any special agreement to the contrary, each has the right to use the invention without accounting to the other, but neither may grant a licence without the consent of the other party. Inventions which may be of use for war and like purposes are sometimes protected by secret patents on the instructions of the Government, and frequently notices are issued drawing the attention of applicants for patents to the desirability of avoiding publication of inventions in cases where the invention relates to munitions of war. In such instances, after lodging an application at the Patent Office and thus obtaining protection, the inventor is advised to submit the details of his invention confidentially to the departments concerned, that is, the Admiralty, War Office or Air Ministry in good time before publication takes place in order that, if considered necessary by such departments, steps may be taken for the invention and any patent granted thereon to be kept secret under the provisions of the Acts on such terms as may be arranged.

It is perhaps important for the public generally to note that if apparatus is made in infringement of patent rights they are likely to have to defend an action brought against them whether the patent be invalid or not. Validity can never be thoroughly tested until an action has been taken to the Supreme Court, which in this country is the House of Lords, and it is a matter of importance when patents are held by powerful concerns who are prepared to spend money in defending them even although they may ultimately fail. In such case defendants, though nominally succeeding in the end are involved in very heavy costs throughout the course of the protracted proceedings.

THE ROYAL SOCIETY SOIRÉE.

(*Concluded from page* 625.)

IN concluding our descriptions of notable exhibits we pass to the "frenophone" of Mr. S. G. Brown, F.R.S., a loud-speaking telephone instrument which seems to recall some of the features of Mr. Brown's electromagnetic relay and of the Johnsen-Rahbek electrostatic relay, but is quite different from these devices. The sound is produced from a telephone receiver of the usual type, the action of which is amplified by friction. A needle is attached to the receiver diaphragm; this needle presses upon a steel pad, smaller than a sixpenny-piece, backed by cork; the pad rests with its cork surface on a slowly-revolving glass disc, and is connected with the large diaphragm of a horn, in which the sounds are mechanically reproduced, by a fine cord. The reproduction obtained was very good.

Among optical exhibits we may mention the new illuminators for opaque objects of Mr. Conrad Beck, a development of the Lieberkühn principle, consisting of an aplanatic ring of glass silvered on the back, which admits of using a short focus reflector of great light intensity with high powers. All glare, caused by the reflection of the object, is removed, and the true colours are seen. By making use of polarised light, the full resolving power of a microscope can be utilised, as Sir Herbert Jackson has shown. Examining some old Egyptian red glass by this means, Sir Herbert was able to identify certain crystals in the glass and thus to imitate the colour.

The advantages of using illuminators of high normal aperture such as those of Messrs. Beck, combined with suitable objectives, were further brought out by the numerous and interesting biological exhibits made by of Messrs. J. E. Barnard, J. Smiles and F. Welch, of the National Institute for Medical Research, Hampstead. This Institute also exhibited a microscope interferometer, made by Messrs. Adam Hilger, but modified so as to serve both for testing microscope objectives and similar optical combinations, and for use as a very highly accurate microscope. One of the demonstrations indicated the effect of altering the tube length (necessary in tests for residual aberration) on the zonal corrections of an objective. This is done by means of a set of four special tube-length lenses; the ordinary measurement range of tube motion is 3 mm., but by means of these special lenses, the control can be extended to 250 mm. The novel mercury-arc lamp and other arrangements admit of taking successive images in any single ultra-violet wave length. The mercury bulb of the lamp is provided with a tubular projection, over which a clay cylinder fits, which is wound with a heater coil; when the lamp is to be switched in, the coil heats the mercury in that tube, the vapour generated breaks the mercury column, and the arc is thus struck.

The chief exhibits of Messrs. Adam Hilger were the improved vacuum grating spectrograph for photography in the ultraviolet (Schumann and Lyman regions) with which Mr. F. Simeon, of the firm, has recently photographed the carbon arc spectrum on colour-sensitived Schumann plates. The instrument is a strong metal tube, about 4 ft. long, to the front end of which a cast plate is soldered, carrying the plate, 6 cm. by 1 cm., and two vertical slits. A horseshoe magnet, projecting in front, can be turned by hand in a collar; by these means a shutter is moved inside so that either the full spectrum, or the upper or the lower half of the spectrum will appear on the plate and two exposures can be made. The Lummer-Gehrcke parallel plate (also shown) with a resolving power of 850,000, made for Professor J. C. McLennan, of Toronto, is a triumphant achievement of Messrs. Hilger; it measures 18 in. by 4 in. by 0·6 in. In the instrument shown by Mr. D. Northall-Laurie, another exhibitor, for mounting microphotographs of crystals so as to show changes of tint, the polarising devices are combined with a selenite plate, the colours of which change from green to red on rotation through 45 deg.

The new recording kata-thermometer of Dr. E. H. J. Schuster, of the National Institute for Medical Research, is an instrument for measuring the cooling power of air currents produced, *e.g.*, by a fan. A U-tube contains mercury and, above it, toluene; in the large bulb, which contains toluene, at the top of one limb, is placed a small platinum coil, and three terminals are fused into the tube. The coil is electrically heated to 100 deg. F. and the current is then automatically cut off; another circuit is automatically established when the temperature has cooled down to 95 deg. F., and the time interval which this cooling takes is recorded with the aid of a seconds pendulum and a swinging lever which draws arcs (consisting of short sections of one second) indicating the cooling periods by their lengths. The thermometer is made by Messrs. J. J. Hicks and the recorder by the Oxford Scientific Instrument Company.

As regards physiological exhibits we can only say that Drs. Leonard Hill and A. Eidinow demonstrated with the aid of quartz cells and mercury lamps, and by other means, that ultraviolet light shows, at 20 deg. C., its biological effects in a third the time it takes to act at 10 deg. C.—an observation considered important, for instance, for the treatment of tuberculosis. Reference to the work of the National Institute of Industrial Industry (under Dr. C. S. Myers) has been made in our columns on other occasions. The exhibits explained the advisability of frosting the bulbs of miner's lamps, and showed the curves of Dr. G. H. Miles and Mr. E. Farmer of improved output (secured by change of work, by rythmical methods of working the pickaxe, &c.), and of Dr. C. Burt's intelligence tests. Mr. M. H. Tagg also explained his vocational tests suitable for entrants to engineering trades, pattern-makers, fitters, turners, draughtsmen, &c.

We finally mention two instructive demonstrations. Mr. Emil Hatschek imitated organic forms by vortex formation, *i.e.*, by running coloured gelatin sol into some coagulating solution, such as aluminium sulphate. With drops of water the vortices are too evanescent; the shrinking gelatin develops radial ribs, undulating membranes, stellate discs and other features, too often still considered characteristic of organic life. Dr. W. Lawrence Ball, F.R.S., showed with the polariscope that the cotton hair has a characteristic convolute form, and that these convolutions are both right and left-handed in any one hair. How this reversal of the spiro-fibrellar structure comes about is unknown; but this structure and the indication of a pseudo-crystalline space-lattice structure are not interesting to the botanist and cotton spinner only.

NOTES.

MODERN ROADWAYS AND FISH LIFE.

IN the early days of the motor car, road tarring proved a pretty effective remedy for the dust nuisance, but complaints were soon prevalent, that when the washings from these roads entered into our streams and other waterways they occasioned a serious mortality amongst the fish. As a consequence of representations, made to this effect, a recommendation was issued in 1922 that highway authorities should give a preference to asphaltic bitumens free from tar products for use on roads draining directly into fishing waters. The belief that drainings from bituminous roads are innocuous has now been experimentally verified by a sub-committee appointed to this end by the Standing Committee on Rivers Pollution. In a report* just issued the committee state that they find both hard and soft bitumens wholly satisfactory. In these the organic matter is mainly composed of unsaturated hydrocarbons, which are almost completely soluble in carbon bisulphide or chloroform. The materials experimented with, were a natural asphalte (A) and a petroleum residue (B), whilst a black oil (C) was used for fluxing purposes. These three materials had the following characteristics:—

	A.	B.	C.
Soluble in chloroform (parts per 100)	57·6	99·8	99·8
Insoluble in chloroform (parts per 100)	42·4	0·2	0·1

The insoluble matter in (A) was nearly all mineral, and none of the three materials contained more than traces of tar acids or bases. In the course of the experiments the washings from road surfaces treated with the foregoing bitumens were concentrated into a pool, containing live trout. In some of the experiments the washings reached the pool practically without dilution, yet the fish remained healthy. Trout, it has long been recognised, are an exceedingly delicate fish, and will perish when exposed to a degree of pollution which coarser fish will withstand with unimpaired vitality.

AN INTERNATIONAL INSTITUTE OF REFRIGERATION.

In the summer of 1920 an International Convention was held in Paris to consider the formation of an International Institute of Refrigeration. Matters progressed satisfactorily and agreement to the formation of such an institute was come to between most of the countries of the world. The most notable name missing is that of the United States. The names of most of the South American Republics are also not included in the list, but that

* Report of the Road Dressings Sub-Committee appointed to study the influence on fish and other forms of stream life of washings from bituminous roads. H.M. Stationery Office. Price 1*d*.

of the Argentine Republic appears. Our enemies in the late war are also not included in the convention. The objects of the institute are to promote knowledge of the science and practice of refrigeration and the study of questions dealing with the preservation, transport and distribution of perishable commodities. It is also proposed to co-ordinate scientific, technical and economic information relating to refrigeration with a view to publication, and to collect and study all laws and regulations dealing with the subject and to submit, if necessary, for the approval of Governments, measures tending to the improvement and unification of regulations respecting the international circulation of products susceptible of benefitting from the application of refrigeration. Finally, it is proposed to organise international congresses. All questions which concern the economic interests and legislation of particular States are, it is stated, excluded from the scope of the institute, but it is not clear that this provision may not run counter to the intention to submit proposals for the improvement of regulations to individual Governments. The general conference will meet every two years and the executive committee at least twice a year. There is to be a salaried staff, including a director, and the various countries concerned are to make annual subscriptions to the funds of the institute, the number of representatives of any country on the general council being determined by the subscription. An annual sum of 12,000 fr. will entitle a country to six representatives. The British ratification of the convention was deposited on January 24 last, but it is not clear what or how many other countries have ratified. The text of the convention, in French and English, has been published as a White Paper at 6*d.* net [Cmd. 1857] and can be obtained through the usual channels.

COPPER ORES.

Copper, whose use probably dates back about eight thousand years, has been gradually ousted from those applications in which iron and steel can be employed with greater success and economy. To-day, however, there is still a large field of service for those purposes for which its characteristics are essential requirements, and among the base metals it holds the second place in importance. For many of its uses it is difficult to find substitutes, and though the Germans were forced to find other materials to take the place of copper, such as electrolytic iron and aluminium, during the European War, when they were isolated from the rest of the world, they quickly reverted to the use of copper on the cessation of hostilities. The importance of the metal in the industrial world is apparent and with the continuous extension of demand, new sources of supply must be opened up. Much useful work has been done by the Mineral Resources Committee of the Imperial Institute in conducting investigations into the distribution of mineral ores, their analysis and assay, and from time to time, monographs have been published on the various minerals. A recent one, on "Copper Ores," written by Mr. Robert Allen, and published by Mr. John Murray, is a most valuable addition to the series, and provides much information regarding the worked and unworked sources of supply. The copper market to-day is not in a very flourishing position, due to the conditions following the Great War. In that period two-thirds to three-fourths of the world's output was used for military purposes. When the armistice was signed large stocks were available and consequently there was a sharp fall in price and the mining operations were curtailed. Whenever more normal industrial and exchange conditions are reached a revival in the industry may be anticipated, as large electrical developments at present under consideration would then be put in hand. Among the producers the United States of America rank highest, the yields from other countries, expressed in percentage of the American figures, are: British countries, 13; Japan, 12; Chile, 10; Mexico, 6; and Peru, 5. Not content with this supremacy, the Americans are increasing their financial holdings in other lands. The mining operations in Britain have practically ceased and the refineries are engaged in the treatment of ores from various parts of the Empire, mainly South-West Africa, India, Canada and Australia, and from foreign lands.

PHYSICS IN THE CERAMIC INDUSTRIES.

In addressing the Institute of Physics, on May 9, on "The Applications of Physics to the Ceramic Industries," Dr. J. W. Mellor, of Stoke-on-Trent, regretted that the professional physicist had not yet taken his rightful place in the organisation of the ceramic industries, where every branch of physical science could render valuable service. Firebricks, he stated, were actually rejected when they did not give a sonorous ring; yet silica bricks, made with precalcined quartz, were not inferior in spite of their leaden ring. As regards light, copper-blue glazes could be matched in artificial light, but cobalt and chrome colours could not. If the absorption spectra of metallic oxides had been better known, certain troubles would not have arisen with cobalt-blue lamp bulbs during the war; the reddish glow of these lamps could be cured by the addition of chromic oxide, but not by copper oxide. Whilst some silica brick makers would be happier if the changes of quartz into α and β tridymite and cristobalite had never been observed by the determination of the refractive indices, others looked to X-ray examination for further help. Iron particles were successfully removed from clay by magnetic separators, but the problem of the separation of cupriferous pyrites by electromagnetic or electrostatic methods remained unsolved, The processes of firing ordinary bricks were efficient; of the fuel spent in firing biscuit ware only 2 per cent. were utilised, however, and improved furnace flues and screens, useful in the early stages of the operations, might be disastrous in the later stages. During the first stages the loss of water and the contraction proceeded at the same rates. Later, the contraction ceased, though the loss of water might continue, and contraction strains should be studied apart from thermal strains. The manufacturer should not be asked whether he could make special shapes, but whether those shapes would leave a good safety margin in manufacture and use. Circular plaques cracked in radial lines, oval plaques in directions towards either focus. When clay passed through a long-nosed pug-mill, a slab cut in the direction of motion had a greater contraction than when taken at right angles thereto. Dr. Mellor had first thought that the wetter clay accumulated near the axis of motion; but the flat particles seemed to travel broadside, like a coin sinking face downward in water. A bat of clay distorted during drying could be straightened by damping and drying it under pressure; but during the subsequent firing the particles contracted along the old paths again. Electric furnaces, invaluable for high-temperature work, were unsatisfactory for pottery firing. Gas and coal firing acted mainly by convection currents, electric heating by radiation; large electrically-heated chambers might be provided with mechanisms to ensure a better gas circulation and convective heating. As regards glazes the many French measurements of the expansion coefficients of glazes and bodies had so far proved of no practical value, not because they were in themselves useless, but because the problems involved were very complex.

THE IRON AND STEEL INSTITUTE.—A most welcome addition to the Proceedings of the Iron and Steel Institute is the Subject and Name Index to vols. lxxxiii–civ (covering the years 1911 to 1921), also to vol. iii–x of the Carnegie Scholarship Memoirs. The index is on the same lines as the preceding ones; the subject-matter portion occupies 203 pages and the names portion 335. It can be obtained from the offices of the Institute, 28, Victoria-street, S.W. 1, or from Messrs. E. and F. N. Spon, Limited, 57, Haymarket. It will greatly facilitate reference to the later work carried out by the Institute.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—At the annual general meeting of this Institution, which is to be held on the 31st. inst., an oil painting of the late Dr. Silvanus Thompson is to be presented to the Institution; Dr. Thompson's library is also to be presented by a number of members of the Institution and others, and a bronze bust of Dr. Thompson, by Mr. Gilbert Bayes, A.R.A., is to be presented by the Finsbury Technical College Old Students' Association. The annual conversazione of the Institution is to be held on Thursday, June 28, at the Natural History Museum, South Kensington.

THE TELECHRON TRANSMITTER.

THERE is undoubtedly a wide field of usefulness for indicators which can be depended upon to show at distant points the water level in a tank, reservoir or canal. For this purpose, instruments working on the galvanometer principle are unsuitable, and thus it has been usual in work of this kind to actuate the indicator at the receiving end of the line by a step-by-step movement, communicated by electrical impulses sent out by a transmitter operated by a float in the tank or reservoir. Great difficulty has, however, been experienced in keeping the receiver and transmitter in step. This has arisen because fairly powerful electromagnets are required to actuate the receiver gear, and in such magnets, the magnetic field can neither be built up nor destroyed instantaneously, but attains its normal value only some appreciable time after the closing or opening of the electric circuit. Hence, if impulses from the transmitting station are sent in too rapid succession, consecutive signals are blurred into one and the receiver and transmitter get out of step.

Troubles of this kind were encountered when it was attempted to secure accurate gaugings of the discharge of the Menufia Canal which irrigates nearly 1,000,000 acres in the delta of the Nile, and this led Messrs. A. B. Buckley and J. S. Wilson, Associate Members of the Institution of Civil Engineers, to design a new type of transmitter, which having proved very satisfactory in service in Egypt is now being introduced here by the Telechron Electric Transmitter Company, of 53, Victoria-street, S.W. 1.

A general view of this transmitter is reproduced in Fig. 1, whilst Fig. 2 represents one model of the receiving and recording instrument. As already mentioned the liability of the transmitter and receiver to get out of step is due to the circumstance that a certain minimum time is necessary for actuating of the mechanism at the receiving end of the line, and hence, if by some accident or other contingency, impulses follow each other in too rapid succession, certain of them would fail to be recorded.

In the new transmitter matters are so arranged, that the rate at which successive signals are sent is constant, and quite independent of the rate at which the float rises or the float wheel (shown to the right in Fig. 1) runs. This float wheel might in fact be moved practically instantaneously through a space corresponding say to 50 impulses, but whilst the whole 50 would be ultimately transmitted to the receiver and recorded there, the rate at which they can be sent is fixed at a safe value by the mechanism provided, and is quite independent of the rate at which the float wheel moves.

Figs. 3 and 4 represent respectively a plan and sectional elevation of the transmitter, the float wheel is shown at A to the right of Fig. 4, and is, it will be seen, mounted on ball bearings and drives by a carrier and follower, the shaft B, on which is fixed a spur wheel C. This wheel follows instantaneously every movement of the float wheel and hence cannot, for the reasons given above, be coupled directly to the gear by which the electric signals are dispatched. In order that the rate at which these signals are sent shall be independent of the rate at which the float wheel moves, it is necessary to make provision for "storing up" temporarily within the mechanism the total motion of the float wheel, and for the subsequent "working off" of this stored motion at a suitable rate. This "working-off" of the stored motion is in fact analogous to the "overtaking gear" fitted to the governor of a steam turbine, which, when the load is changed and the relay valves displaced, ultimately restores these valves to the same relative position as they had before the change of load. In such cases the "overtaking" motion is generally provided for by a floating lever, which in the present case finds its mechanical analogue in an epicyclic gear mounted on the disc D, which it will be seen is supported by a sleeve which is loose on the shaft B. This sleeve carries on the right a ratchet wheel E, by the step-by-step motion of which any displacement of the epicyclic gear due to a rise of the float wheel is ultimately worked off. This epicyclic gear in fact stores up the total "instantaneous" motion produced by a rise of the float.

The first effect of such a rise and consequent movement of the epicyclic gear is to set in operation an electric relay which "notches round" the ratchet wheel E tooth by tooth until certain relative positions of the mechanism are restored to what they originally were. The same current which operates this relay passes also through the distant receiving instrument and notches round its indicator in a similar way.

It is, of course, necessary to provide both for a fall and for a rise of the float, and this involves a certain duplication of parts in the transmitter, which, however, may be ignored for the present, as the mechanism will be more easily understood if, in the first instance, we describe it as having to deal only with displacements due to a rise of the float.

One of the planet wheels, of the epicyclic train, gears, it will be seen, with the wheel F which rides loose on the shaft B. By additional gearing, introduced to provide for falls of the float, and the details of which we shall for the present ignore, the motion of this wheel F is communicated to the sleeve X, which is loose on the shaft B, and the motion of this sleeve is in turn transferred to the shaft H of a sort of engine counter mechanism enclosed in the box G.

When the float wheel rises therefore it drives round F through the epicyclic gear and the shaft H is turned through an angle proportional to the total rise.

Let us assume that the mechanism is in its normal position and that the float suddenly rises, causing H to rotate.

The only direct effect of the motion of H is to raise a small detaining pawl, and this it accomplishes at the very outset of its motion. The raising of this pawl or catch releases the pivoted quadrant shown at I, on the left of Fig. 4, and, once set free, this quadrant falls by its own weight, and by means of a contact-maker mounted on its lower edge closes a circuit through the swinging arm J, which is best seen in Fig. 5. In this way a circuit is completed both through the distant receiver and through a local electromagnet shown at K, Figs. 4 and 6. This magnet, with its armature L (Fig. 6), constitutes the electric relay to which reference has already been made.

As a consequence of this magnet being energised the swinging armature L is pulled over, and this armature is connected by shafting and link work with the contact arm J (Fig. 5). As a consequence, this arm is swung up, carrying with it the quadrant I (Fig. 4), which, in fact, it throws up beyond its original position. Were not provision made for ultimately restoring to its original position the detent which originally sustained the quadrant, the relay would continue to work indefinitely. This follows because, when the quadrant is thrown up as described contact is broken, the magnet is demagnetised and the armature restored to its original position, so that when the quadrant falls again and closes the contact the motions just described are repeated. During the original swing of the armature, however, the ratchet shown in Fig. 6 gathers a tooth on the wheel E, and when the current is broken and the armature falls back, this ratchet pushes the wheel E round through one tooth, and as a consequence the epicyclic gear rotates the wheel F (Fig. 4) through one step in the opposite direction to that in which it was moved by the rise of the float. Hence by repeated motions of this kind the shaft H (Fig. 4) is ultimately restored to its original position, and when this is attained the next time the quadrant I is flung up it is caught by the catch which originally sustained it, and the movements are brought to an end.

Obviously the further the wheel F was displaced by the original rise of the float, the further round must the wheel E be ratchetted in order to cancel the original displacement of the shaft H, and as already explained each movement of E is preceded by the transmission of a current to the distant recorder.

The rate of fall of the quadrant I which closes the circuit is regulated by a small fan mounted on a shaft geared with the quadrant. Hence the fall of the latter is spread over a sensible period of time, and sufficient interval is thus secured between successive signals to ensure the proper working of the recorder. The fan is, it may be added, loose on its shaft, being driven by a ratchet mechanism like that used on a keyless watch, and is thus rotated only on the downward motion of the quadrant, the upward motion of which is accordingly unimpeded.

As already indicated the shaft H operates a train of wheels, arranged on the principle of a revolution counter. In the normal position the relationship of these is such that the wheel which, in a counter, corresponds to the hundreds wheel is just ready to move. Hence the motion of the unit wheel through a single step in either direction will carry with it this hundreds wheel, which, in making this motion, releases a catch as already described, and thus sets the relay in action. Before the unit wheel (moving in the same direction) can again affect the hundreds wheel, it must be moved through 100 steps, and hence a rise of the float equivalent to 100 steps can be stored up in the mechanism and worked off at leisure by the backward rotation of H, which is communicated to it by the operation of the electric relay.

The working of the instrument has been described as if merely a rise of the float had to be dealt with. Actually, of course, it is essential to record both rises and falls. This involves a duplication of parts, but does not necessitate the introduction of any new principle.

A second quadrant corresponding to I is provided on the other side of the box G (Fig. 4), and this quadrant is released by H, when the float falls, and there is a second electromagnet (shown at M, Fig. 4) which operates in exactly the same way as K, throwing up its quadrant and ratchetting round a wheel N (Fig. 4), which is mounted on a sleeve which carries the second epicyclic gear represented at O (Fig. 4). The operation is exactly the same as has been already described. It should, however, be added that both ratchet wheels E and N are locked against motion in either direction save when being actually ratchetted round by their relays.

Should the transmission line be broken down or the battery fail, the transmitter, on the defects being made good, will automatically set the receiver in step with itself. The most unfavourable case that can happen is that whilst the line is out of service, the float first rises so as to release one quadrant and then falls so much that the other is also released. In that case when current is restored to the line both the "rising" and the "falling" contacts are closed, and two conflicting impulses are transmitted to the receiver. To provide for this, the actuating mechanism of the receiver embodies a differential gear, one wheel of which is operated by a rise of the float at the transmitting end and the other by a fall of the float. If the two conflicting impulses arrive together, both wheels of the differential are moved, with the result that the index is unaffected, the one motion cancelling the other. At the transmitting end, when the current is completed under the conditions stated, both the quadrants are flung up simultaneously on current being restored to the line. One of the two will, however, always find its retainer in position to catch it, but the other will fall back again, making a fresh contact, and sending a new impulse to the receiver, and this action will be continued as already described until the whole of the resultant motion of the float which has been "stored up" in the mechanism of the transmitter has been completely worked off.

Of course, there are many other obvious applications of the apparatus, besides that of recording water levels at a distance.

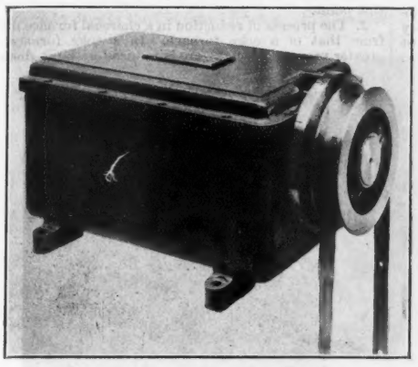


FIG. 1. THE TRANSMITTING ELEMENT.

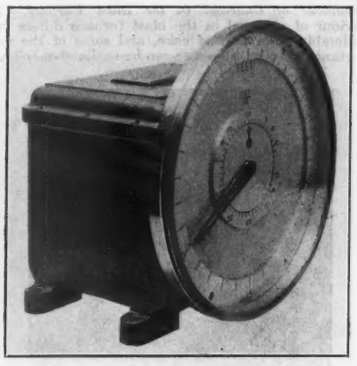


FIG. 2. THE RECORDING ELEMENT.

Fig. 3. PLAN, COVER & FLOAT WHEEL REMOVED.

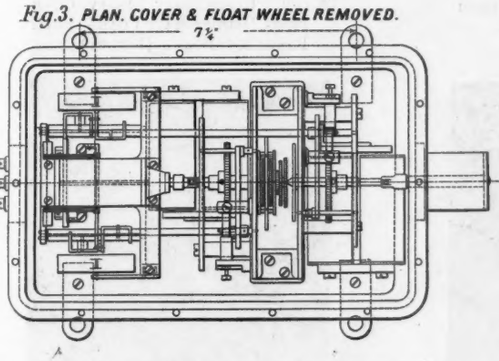


Fig. 5. END ELEVATION OF MOVEMENT.

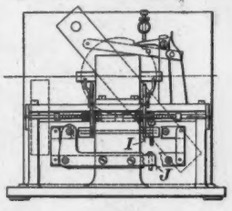


Fig. 4. PART SECTIONAL ELEVATION WITH FLOAT WHEEL.

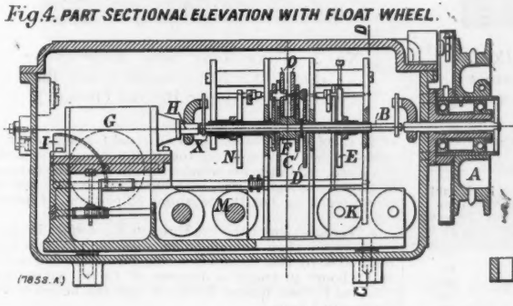
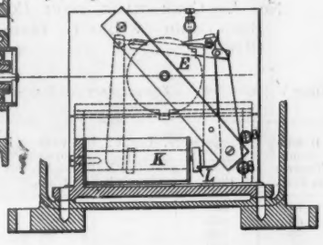


Fig. 6. SECTION ON C.D.



TRAINING OF NAVAL STOKERS.—We understand that the classes which have been held during the last six months at Portsmouth, Chatham and Devonport for acting leading stokers, are now to be extended at the two first-mentioned ports. Before being confirmed in the rating of leading stokers, the men have been given a three-months course of training, but hitherto only one class, containing 20 men, has been carried on at each port. The new Admiralty order, however, provides for the formation each month at both Portsmouth and Chatham of a class of 20 men, so that three classes will be running simultaneously at those ports, although the arrangements in the Devonport division will not be altered.

THE RAILWAY YEAR BOOK FOR 1923.—Exceptiona interest attaches to the twenty-sixth edition of the Railway Year Book, which appeared recently. The grouping of the railways during the past year has necessitated very considerable revision of this annual, and the work appears to have been well executed, while the lists of officials are rather surprisingly complete in view of the length of time which elapsed before definite announcements were made in the case of some appointments. Possibly the future may show the desirability for some modification in the treatment of the grouped railways, but the method adopted in the present volume maintains to some extent continuity with its predecessors, while giving all possible information regarding the new phase now entered upon. The usual features regarding passenger train services have, of course, been brought up to date, and it will be noted that the present services do not fall so far short of those of pre-war days, as is often stated to be the case.

BLAST FURNACE COKE.

*The Reactivity of Coke as a Factor in the Fuel Economy of the Blast Furnace.**

By E. R. SUTCLIFFE and EDGAR C. EVANS.
With a Note by R. V. WHEELER.

(*Concluded from page* 640.)

Methods of Producing an "Active Fuel."—The authors' work with reference to the production of an active fuel has developed upon somewhat novel lines. Their views regarding the theoretical aspects of the question were recently presented in a paper to the Society of Chemical Industry.† They found that the combustibility of a carbonised fuel is primarily dependent not so much on the percentage of volatile matter it contains as upon its structure. Provided care be taken to obtain a certain characteristic structure in the resulting product, a coal can be carbonised at practically any temperature, in practically any type of carbonising system, and still retain an extremely high degree of combustibility. The factors involved in the production of this structure can be summarised as follows :—

(A) Preparation of the coal prior to carbonisation :—
(1) Efficient cleaning.
(2) Preliminary treatment or blending of coals or coke to ensure a minimum of swelling in the retort.
(3) Fine grinding of the coal.
(4) Briquetting of finely divided coal mixture.
(B) Carbonisation of the coal as slowly as possible consistent with economic requirements.

The general methods adopted to effect these results have been outlined in a paper by the authors to the South Wales Institute of Engineers.‡ The characteristics of the structure of the resulting fuel can be summarised as follows : (1) Extensive area of surface per unit of mass. (2) High porosity. (3) Minute size of cells. (4) Pronounced porosity of cell walls. (5) Greater degree of continuity of cell structure than is the case with ordinary blast-furnace coke.

The accompanying photomicrographs (Figs. 1 to 6), taken by Sir George Beilby, and reproduced by his kind permission from a paper by him to the Society of Chemical Industry§, give an indication of the difference in structure existing between different types of coke. In this paper Beilby expressed the opinion that the ultimate coke substance is in every case—from wood charcoal to coke—of a vitreous character—"it is a true glass"—and that the main factors in the production of a reactive coke area are :—

(1) The area of the reactive surface in the coke.
(2) This is influenced by the size of the cells and the thickness of the cell walls—the more minute the cells and the thinner the cell walls, the greater the area of reactive surface.
(3) The accessibility of the reacting gases to the interior of the coke mass.

The whole subject, from a theoretical standpoint, is extremely fascinating, and opens up a field of immense possibilities not only in the fuel and iron and steel industries, but in practically every sphere of chemical and metallurgical practice. For the moment, however, all that is necessary to say is that by suitable methods of treatment a fuel can be obtained of hardness equal to that of metallurgical coke, of density approaching that of coal, and with a combustibility or "reactivity" of the order of that of charcoal.

The following particulars of such a fuel may be of interest :—

Analysis of "Pure Coal Briquette" Coke.

	Per Cent.
Ash	8·0
Volatile matter	0·75
Apparent specific gravity	1·20
True specific gravity	1·80
Volume of cells	33·3

These results, together with those submitted by Professor Wheeler and his collaborators at the end of this paper, show that a material prepared in the manner outlined possesses the properties both of coke and charcoal (differing, however, in the very high apparent specific gravity that it possesses). The authors venture to believe that the use of a fuel of this character will allow of considerable economies being effected in the fuel consumption of blast furnaces.

This view, of course, is based as yet purely upon theoretical considerations, and pending a large scale trial, it is impossible to say how far they are correct or not. It might, however, be of interest to outline some of the theoretical considerations which point in this direction. In view of the similarity of reactive coke to charcoal, it is advisable to examine the behaviour of charcoal in the blast furnace.

Behaviour of Charcoal in the Blast Furnace.—The behaviour of charcoal in the blast furnace differs very considerably from that of coke, and some of the most important points of difference can be outlined as follows :

1. The temperature gradient in a charcoal furnace differs from that of a coke furnace. Table V, adapted from particulars given by Bell,* gives the temperatures observed in two coke blast furnaces 72 ft. and 48 ft. high, and in a charcoal blast furnace 35 ft. high.

The temperature in the charcoal furnace falls rapidly within a distance of only 15 ft. from the tuyeres, and this points to powerful endothermic reactions in that zone. These may be due to :—

(1) The dissociation of limestone and evolution of CO_2.
(2) The direct reduction of oxide of iron according to the equations :—

$$Fe_2O_3 + 3C = 2Fe + 3CO - 108{,}120 \text{ calories.}$$
$$FeO + C = Fe + CO - 36{,}540 \text{ calories.}$$
$$2FeO + C = 2Fe + CO_2 - 34{,}200 \text{ calories,}$$

or (3) The solution of carbon in carbon dioxide—

$$CO_2 + C = CO - 38{,}880 \text{ calories.}$$

The drop in temperature from a point 15 ft. above the tuyeres to the outlet is such as approximately to balance the heat absorbed by the incoming burden. It may be assumed that little chemical reaction takes place above this point.

2. The process of reduction in a charcoal furnace differs from that of a coke furnace. In a coke furnace the greater proportion of the ore is reduced within a distance of 25 ft. of the throat.* In a charcoal furnace, working with low fuel consumption, the greater proportion of the ore is reduced in the lower reducing zone near the tuyeres. Ebelman has shown that with charcoal furnaces the ore might reach the hearth containing 50 per cent. of ferrous oxide.

3. The passage of the ore through the surface is much more rapid than with a coke furnace. In one case referred to by Bell the ore in a coke furnace took a period of 12 hours to travel a distance of 15 ft., whilst in a charcoal furnace quoted it travels half the height of the furnace in 1 hour.

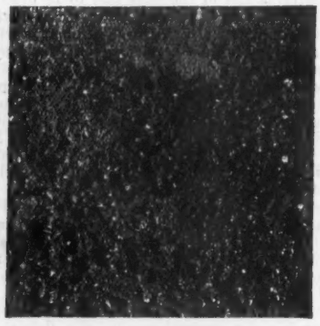
4. Appreciable quantities of carbon dioxide are found in every portion of the furnace, whilst in the case of a coke furnace very little additional carbon dioxide is found below the zone of limestone decomposition until the vicinity of the tuyeres is reached.

5. The output per cubic capacity of a charcoal furnace is generally higher than that of a coke furnace.

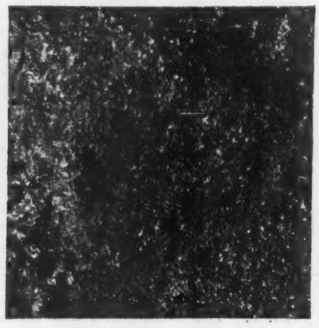
6. Less carbon deposition occurs in a charcoal furnace than in a coke furnace.

Reviewing generally the work done in the charcoal furnace, it appears that there is a far greater difference between the behaviour of charcoal and coke than would be accounted for by the difference in chemical composition (sulphur, ash contents, &c.). The difference is one primarily connected with the reactivity of charcoal compared with coke. This results in the following series of consequences :—

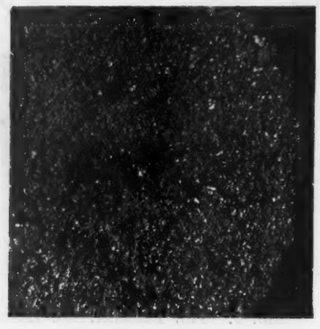
(1) Consumption at the tuyeres can be effected more rapidly.
(2) Rapid lowering of the burden.
(3) Reduction is delayed.
(4) Larger proportion of direct reduction in the lower reducing zone near the tuyeres.



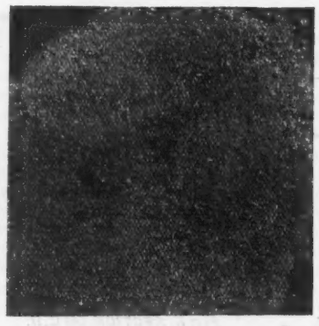
No. 1. GAS COKE MADE IN HORIZONTAL RETORTS FROM DURHAM COAL (BEILBY).



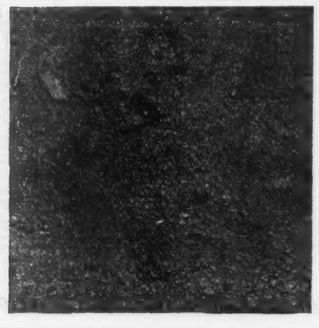
No. 2. BLAST-FURNACE COKE FROM RECOVERY OVENS (BEILBY).



No. 3. LABORATORY ASSAY COKE FROM DALTON MAIN COAL.—FUEL RESEARCH BOARD (BEILBY).



No. 4. COKE MADE FROM COAL BRIQUETTED WITHOUT BINDER (BEILBY).



No. 5. COKE MADE FROM MIXTURE OF CAKING AND NON-CAKING COALS BRIQUETTED WITHOUT BINDER (BEILBY).

TABLE V (*from Bell*).—*Temperatures in Coke and Charcoal Furnaces.*

Height from Tuyeres in Feet.	Temperature. Deg. C.		Coke Furnace 45 Ft. High.	Height from Tuyeres in Feet.
	Coke.	Charcoal.		
70	335	—	—	70
65	455	—	—	65
60	540	—	—	60
55	650	—	—	55
50	825	—	—	50
45	925	—	400	45
40	980	—	455	40
			650	
35	—	90	825	35
		160	925	
30	1,010	340	—	30
		550	980	
25	—	640	1,010	25
		680		
20	—	—	—	20
15	—	840	—	15
		910		
10	—	950	—	10
		1,150		
5	—	—	—	5
Tuyeres	—	—	—	Tuyeres

* Paper read at the meeting of the Iron and Steel Institute, on Thursday, May 10.

† Journal of the Society of Chemical Industry, June, 1922, vol. xli, pages 196T to 208T.

‡ Proceedings of the South Wales Institute of Engineers, July, 1922, vol. xxxviii, page 341.

§ Journal of the Society of Chemical Industry, 1922, vol. xli, No. 21, pages 341T to 347T.

* "Principles of the Manufacture of Iron and Steel," pages 72 and 295.

* *Op. cit.*, pages 219–2 and 295.

(5) More reduction may be thrown on the hearth without derangement.

(6) Greater solution.

Solution, however, is not attended with any serious loss to the efficiency of the furnace, as was shown by Howland's analysis. Solution takes place principally in two zones, viz.: (1) The zone of limestone decomposition, and (2) the lower reducing zone near the hearth.

Any carbon monoxide given off as the result of the action of carbon dioxide on carbon in the zone of limestone decomposition is still at such a temperature as to be able to effect reduction of the ore lying above it, whilst the carbon monoxide produced by solution in the hearth is at such a temperature as to be equivalent in reducing power to gas produced by combustion. This is shown by the analysis given later.

There is one point which has important consequences, and that is that carbon deposition is less pronounced in charcoal furnaces than in coke furnaces. In a furnace

No. 6. ENLARGED MICRO-PHOTOGRAPH OF GAS COKE MADE IN VERTICAL RETORTS (BEILBY).

where reduction takes place at a temperature of 400 deg. to 500 deg. C. carbon deposition is greatly facilitated; this action results in the evolution of heat, due to the reaction, $2CO = C + CO_2 + 38{,}880$ calories, and this, combined with the heat released by the reaction of $Fe_2O_3 + 3CO = 2Fe + 3CO_2 + 8{,}520$ calories, further tends to induce the reduction of the burden in the upper reaches of the furnace; in short, these reactions are self-supporting in regard to heat development, and the height of a furnace could be increased indefinitely without stopping it.

The heat released in this way is largely lost to the furnace, being expended in heating up the furnace gases and increasing the loss due to radiation. It is true that the deposited carbon is returned to the furnace subject to such loss as passes away in the flue dust, but the carbon has the serious effect of splitting up the ore into powder and impeding the free passage of the gases, and the reduced iron reaches the melting zone surrounded with fine carbon, which seriously impedes the coalescence of the iron globules as they melt. It also acts as a non-conducting material, preventing rapid heating up of the burden. It does assist, however, to some extent to carburize the iron. On the other hand, where the reduction takes place, as in a charcoal furnace, principally at a high temperature from 850 deg. to 1,000 deg. C., the tendency to deposit carbon is much less pronounced and the ore is reduced in lump form, which offers less resistance to the blast and melts far more readily.

The effect of deposited carbon is therefore to produce a loss of heat, and is one of the reasons for a coke furnace requiring a hotter zone for the final heating and melting of the charge.

After the above review of the conditions in a charcoal furnace, it might be possible to outline the special characteristics of a reactive fuel in the blast furnace. It would differ to some extent in its action from charcoal, owing to the difference in its properties.

Differences between Reactive Coke and Charcoal.—1. The apparent specific gravity of the coke is much greater than that of charcoal. It is, in fact, greater than that of ordinary coke. This would have the following consequences:—

(*a*) The space occupied by the ore and the limestone would be considerably increased.

(*b*) The period of contact of the reducing gases with ore and limestone would be much greater than in a charcoal furnace.

(*c*) Whilst this coke might be burned at the tuyeres as rapidly as charcoal, yet the volume occupied by the coke would only be about half that occupied by charcoal, so that the burden would not be lowered so rapidly as is the case in a charcoal furnace.

(*d*) Owing to the greater mass of fuel per unit of volume occupied, the zone of oxidation at the tuyeres would probably be less than is the case with charcoal.

(*e*) The combined effect of these differences would probably result in an economy of fuel as compared with charcoal, due to the following causes:—

(1) The smaller oxidising zone at the tuyeres would reduce the secondary oxidation of the spongy iron, with its consequent waste of fuel.

(2) From Korevaar's equation, the smaller oxidising zone would be accompanied by a hotter hearth than is the case with charcoal.

(3) Reactive coke is much harder than charcoal. There would probably therefore be less breakage, less channelling, and a more even distribution of the reducing gases in the furnace.

(4) Furnaces using coke can be built of much greater capacity than is the case with charcoal, thus allowing increased blast temperature, and resulting in reduced radiation and other furnace losses per unit of iron produced.

(5) Against these advantages, however, would be the increased ash and sulphur in the fuel as compared with charcoal. The increased fuel consumption due to these impurities can, however, be calculated, and on the balance theory points to the view that the economies would outweigh the losses.

Characteristics of a Reactive Coke in a Blast Furnace.—One of the most important features of a reactive coke would be the effect it would have, in common with charcoal, of lowering the zone of reduction in the furnace, thus enabling the furnace reactions to be carried out at a much higher temperature than is the case with an ordinary coke. In fact, with a reactive fuel there is every probability that a larger proportion of reduction would be effected in the hearth than is the case with ordinary coke, with corresponding economy of fuel.

Let us consider the reactions taking place in a furnace operating like a charcoal furnace, in which a large proportion of the reduction takes place at a high temperature. There is one important feature in this connection which is not generally realised, and that is that the reducing reactions at a high temperature give out considerably more heat than at a low temperature. Thus:—

At 900 deg. C. the reaction

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2$$

gives out 21,695 calories as against 8,520 calories at ordinary temperatures.*

At 830 deg. C. the reaction

$$FeO + CO = Fe + CO_2$$

gives out 8,724 calories as against a heat absorption at 580 deg. C. of 3,100 calories.†

On the other hand, the following heat-absorbing reactions can take place, viz.:—

At 900 deg. C.

$$2Fe_2O_3 + 3C = 4Fe + 3CO_2 - 66{,}670 \text{ calories.}$$
$$FeO + C = Fe + CO - 14{,}000 \text{ calories (?)}$$

The latter reaction is accompanied at ordinary temperatures by a heat absorption of 29,060 calories. The specific heat of ferrous oxide is not known at high temperatures, but on the assumption that it was similar to that of ferric oxide the heat absorption at 900 deg. C. would be only 14,000 calories.

It is evident that the heat-producing reactions, once started, proceed with greatly increased rapidity as the temperature rises, and once they commence at high temperatures, given the necessary supply of CO from the hearth, they go on to completion giving out heat, and if there were no other reactions of an opposite nature, the temperature of this part of the furnace would go on increasing. The heat produced, however, finds utilisation in facilitating the heat-absorbing reactions in such a way as to promote the attainment of balance between all the reactions in this zone.‡

From observations made in a charcoal furnace this balance between the opposing reactions would be obtained at 850 deg. C., when the carbon monoxide and carbon dioxide are approximately in equal proportions.

Assume that the reduction of ferric oxide proceeds thus: $Fe_2O_3 + 2CO = 2FeO + CO + CO_2$, and that the resulting ferrous oxide is reduced by solid carbon according to the equation, $2FeO + 2C = 2Fe + 2CO$. Since the carbon monoxide produced by the latter reaction is utilised in reducing ferric oxide, then, in effect, reduction of two atoms of iron have been effected by two atoms of carbon, which is perhaps the minimum carbon consumption for the reduction of ferric oxide, and is equivalent to 4·28 units of carbon for 20 units of iron.

If, however, we first burn carbon at the tuyeres thus: $6C + 3O_2 = 6CO$, and use these six molecules of carbon monoxide thus: $Fe_2O_3 + 6CO = 2Fe + 3CO + 3CO_2$, it has taken exactly three times as much carbon, or an equivalent of 12·84 units per 20 units of iron and given out 8,520 calories. If, therefore, we can utilise the heat generated in the latter reaction to facilitate the former, a distinct gain in economy is effected.

It is not absolutely necessary for direct reduction to take place; the same ultimate results can be obtained by intermediary action of carbon dioxide thus:—

$$3CO_2 + 3C = 6CO;$$
$$Fe_2O_3 + 6CO = 2Fe + 3CO + 3CO_2.$$

The above reactions are equivalent to $Fe_2O_3 + 3C + 3CO_2 = 2Fe + 3CO + 3CO_2$, and the ultimate result is the reduction of two atoms of iron by three atoms of carbon.

The property of solubility in a fuel instead of being detrimental results therefore in a saving of fuel. It allows of heat-absorbing reactions taking place side by side with reactions which give out heat, which, however, is wasted if allowed to take place in the upper portions of the furnace. Activity of the carbon facilitates considerably the reduction of the ore by some such series of reactions as outlined above.

The crux of the ore whole position lies in the hearth.

* Richards, "Metallurgical Calculations," page 128.

† Mahler, Journal of the Iron and Steel Institute, 1905, No. 1, page 645. *Revue de Metallurgie*, 1904, vol. i, page 493.

‡ The term "balance" is used advisedly, in order that it may not be confused with the conception of equilibrium between the reactions. Equilibrium between reactions generally is associated with sufficient time for the reactions to proceed to completion. In the case of the blast furnace the time permitted is so small that final equilibrium cannot be attained.

This is essentially the laboratory of the furnace. In this zone the temperature and other conditions are such that reactions take place in exceedingly short periods of time as compared with the other portions of the furnace. This is the zone in which modifications of the conditions have been most fruitful of results from the point of view of fuel economy, whilst theory as well as practice support the view that pronounced activity in the fuel arriving at this zone would have far-reaching results on the thermal efficiency of the furnace. From the practical standpoint, the results obtained with hot-blast, and later with dry blast, show that a small increase in the chemical and thermal activity of the hearth reactions play a very much greater part in determining the final fuel economy of the furnace than would ever have been calculated from the old-time thermal balance-sheet.

From a theoretical standpoint the critical temperature theory opens up considerable possibilities in the employment of an active fuel, and whether the theory be true in all its applications or no, the conception is one which so far as the hearth is concerned, does explain some of the more obscure phenomena in blast-furnace practice.

In all probability the increase of activity in the fuel will result in a contraction of the zone of combustion, with at the same time an increase of temperature. Further, not only will the temperature be increased, but at the same time the critical temperature will be reduced.

Johnson defines the critical temperature as the free running temperature of the slag, which is determined largely by the composition of the slag. One of the most important factors in determining the free running temperature of the slag is the proportion of sulphur in the fuel. Johnson* states that sulphur removal can be effected by: (1) Increasing the lime in the slag, or (2) by increasing the hearth temperature. An increase in the lime content, however, results in a rapid increase in the free running temperature of the slag. The available heat therefore is reduced, and to supply this an increased expenditure of fuel is necessary.

On the other hand, Johnson points out that "an increase in blast temperature is much more effective in promoting desulphurisation than a considerable increase in limestone." This established fact of practice agrees with the results of the investigation of James Bell, which tended to show that with a slag of moderately basic character a considerable proportion of the sulphur is eliminated by volatilisation, an action which is prevented to a large extent by an excessively basic slag. A reactive fuel, by increasing the hearth temperature reduces the basicity required in the slag.

A further important consideration which has a bearing upon the critical temperature is the carburisation of the iron, a by no means negligible feature in the furnace operations.

Reactivity of the coke increases the rate of carburisation of the iron as is shown by the following experiments which are typical of a series conducted.

Mild steel turnings intimately mixed with equal weights of the fuels specified (graded in size between 12 and 14 mesh) were gradually raised to a temperature of 1,100 deg. C. and maintained at that temperature for 13 hours. The carbon content of the steel was increased as shown in the following table:—

Fuel Used.	Carbon in Original Steel. Per Cent.	Carbon in Steel after Treatment. Per Cent.
Foundry coke	0·08	0·45
Fuel prepared as described on page 664 ...	0·08	1·89
Wood charcoal	0·08	1·79
Precipitated carbon ...	0·08	1·15

The melting-point of pure iron is about 1,500 deg. C., whereas the melting-point of iron containing 1·9 per cent. carbon is about 1,150 deg. C. Therefore, if conditions in the furnace permit of the more easy absorption of carbon, such iron could be melted more readily, and a lower temperature would suffice.

There is finally a most important feature in connection with blast furnaces to be considered. First, however, the function of the operation is to reduce and melt the iron leaving as little iron in the slag consistent with economy and the resulting quality of the iron; but maximum economy will only be obtained when the full power of the furnace is utilised. If, therefore, it be possible to obtain the results required by using not only the reducing power in the shaft, but also to permit reduction to take place in the hearth and still secure the desired quality, output and iron residues in the slag, a further step to fuel economy will have been achieved.

Now, as already observed, in a charcoal furnace with low consumption, considerable reduction takes place in the hearth, and such reduction, owing to the conditions, must mainly be effected by solid carbon. As shown from a chemical standpoint, such reduction is effected with one-third the carbon required for reduction by carbon previously oxidised at the tuyeres; hence, provided this can be done and the required temperature and heat balance still retained, so much to the good will have been obtained.

When the slag and metal has melted in the bosh it trickles down over the slag and stone, and gradually reaches the hearth, and it is known that as it does so, it does not at first exist in the state in which it leaves the furnace; the slag still contains much oxide of iron, and the iron still has to dissolve further carbon. For the present only the slag containing ferrous oxide need be considered. Assuming that the ferrous oxide has in the main to be reduced before arrival at the hearth, it must, being in this liquid state, receive its carbon by actual contact. Let us therefore follow as well as we can the course of a drop of such slag on its way to the hearth.

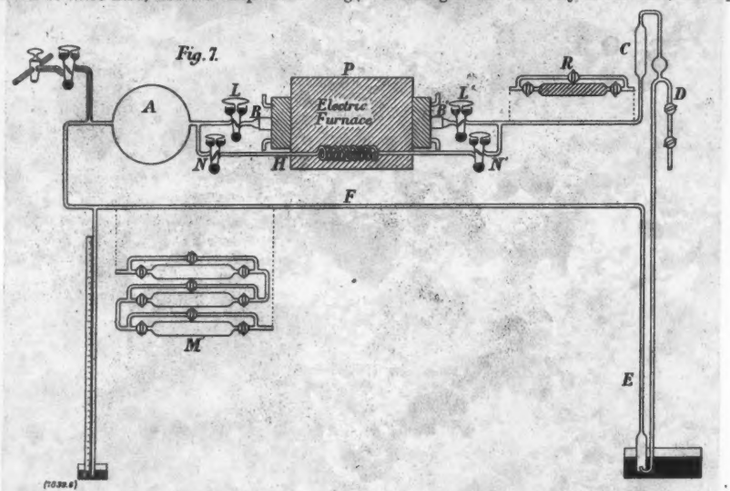
* *Op. cit.*, page 199 *et seq.*

Assume the furnace to be using ordinary refractory coke and operating normally. In such circumstances the furnace will have adjusted itself to the conditions and will be running with slag still containing some iron; with a refractory coke the critical temperature compared with a charcoal furnace will be high, and owing to that high temperature the coke will be in an active state.

As a drop of slag falls on the coke, the reaction $FeO + C = Fe + CO$ will take place at the point of contact and take place instantly, and this reaction is one accompanied by loss of heat. Since the specific heat of ferrous oxide is not actually known at high temperatures, it is not possible to ascertain the extent of this loss at high temperatures, but calculated from zero, the heat absorbed would be 36,528 calories. This loss of heat would have the effect of solidifying the drop of slag momentarily and checking its fall until it had collected sufficient heat again to permit it to continue its course. In this way the temperature of the furnace, by rendering the carbon active, has checked the passage of the slag and permitted it to collect further heat to allow the reaction to be repeated, until by the time it enters the bath, little further reaction remains to be effected there by contact with the coke submerged in the well.

If the slag contain little ferrous oxide, this delayed action will be less, and it will run more freely to the hearth; thus, if reduction be more complete in the shaft, little delay will occur.

Now consider the same drop of slag in a similar furnace running cold. Under such conditions the slag will have adjusted itself and will contain more ferrous oxide. Hence it will be more fluid, and the temperature being



lower, the reaction between the carbon and ferrous oxide will not be active and the delay will be less marked, with the result that in this case the slag arrives at the bath in an unreduced condition.

Now consider a similar drop of slag in a furnace using charcoal or a very reactive coke. As it will be running to take as much surplus heat from the hearth as possible, the slag may contain at the outset far more ferrous oxide than in a coke furnace, and the critical temperature will be lower, but in this case the fuel is far more reactive at this temperature than the hotter coke furnace, and the reaction ferrous oxide + carbon is far more intense. This condition retains and delays the slag, until the final traces of iron are reduced prior to its arrival at the bath. The above theory accounts to some extent for the increased carbon dioxide in the hearth of a charcoal furnace.

Assuming the correctness of the above views, it means that from the hearth considerable quantities of carbon monoxide will be rising, and as the blast enters it will combine with either carbon or carbon monoxide; if carbon monoxide, it will produce carbon dioxide, which will react with carbon to form carbon monoxide. If 25 per cent. of the oxygen be removed in this region, quite appreciable amounts of carbon dioxide could appear in the gas analysis. A further point bearing upon this is that, assuming the deductions to be correct, the slag running in a charcoal furnace to the bath with a larger ferrous oxide content would have a lower melting-point, which all bears upon the deduction that a lower critical temperature is required for such a furnace than in a coke furnace.

Effect of an Active Coke on the Output of the Furnace.—The output of a furnace is dependent on the rapidity with which the fuel is consumed. In the past this has been measured per square foot of hearth area. Johnson* however, points out that this basis was not a correct one. Combustion proceeds not in a plane, but in a zone embracing probably the whole of the bosh, and a more correct view would be the coke consumption per cubic foot of bosh space (see above). Owing to the velocity with which the blast passes through this region, the time available for the oxygen in the air to be converted into carbon monoxide would be less than one-third second, a time so small that combustion would only proceed in the outer surface of the coke. The air would not permeate into the interior of a coke lump.

It has been shown by Sir George Beilby† that a coke prepared in accordance with the procedure outlined on page 664 is characterised by an extremely large surface area per unit of mass. In view of this, combustion could proceed with greater rapidity than is the case with normal blast-furnace coke. In other words, it would be possible with increased blast to burn an increased quantity of fuel in the hearth. On the other hand, owing to the reactivity of the fuel and the larger proportion used in the furnace for direct reduction for the same blast, a larger consumption of fuel would be obtained with a more rapid lowering of the carbon, and consequently an increased output.

Assuming that an ordinary coke furnace producing 20 cwt. of iron with 20 cwt. of coke, all of which was consumed at the tuyeres in accordance with Gruner's ideal, and further assume that with a reactive coke a ton of coke was used per x cwt. of iron, of which 10 cwt. only was consumed at the tuyeres, then the output of such a furnace would be doubled, since its output depends upon the quantity of fuel the blast could consume.

This increase would reduce the heat losses, *e.g.*, radiation, &c., which are dependent upon the time factor.

Summary of Fuel-Saving Factors involved in Use of Active Coke.—It is now possible to summarise in a general way the various fuel economies that would be effected by the use of an active coke.

Taking the heat-absorbed side of the thermal balance-sheet, the following changes could be expected:—

1. Less limestone would be required—hence less heat would be absorbed by its decomposition.
2. Less slag would be made.
3. Owing to the reactivity of the coke, the top temperatures would be lowered, hence the loss in sensible heat would be reduced.
4. Owing to the smaller blast required per unit of iron with an active coke, the volume of gases leaving the stack would be lower than is normally the case, still further reducing the loss in sensible heat.

On the heat-produced side of the thermal balance-sheet, the proportion of carbon dioxide in the exit gases would be considerably increased.

Lastly, from the point of view of the chemical side, the carbon requirements for the reduction of the ore would probably be much lower than is normally the case—owing to the increased amount of direct reduction that would take place.

The sum total of these effects is very difficult to estimate quantitatively, but an attempt can be made in a very imperfect and tentative kind of way to get some idea of their numerical value in a furnace operating with reactive coke under ideal conditions.

The Limits of Fuel Economy in a Blast-Furnace from a Chemical Standpoint.—The carbon requirements in a blast furnace, working in accordance with Bell's hypothesis, can be calculated from the equation:

$$Fe_2O_3 + 9CO = 2Fe + 6CO + 3CO_2.$$

This equation requires the use of 19·6 cwt. approximately of coke per ton of pig.

On the assumption that reduction was effected entirely by carbon monoxide, and that the resulting proportions of carbon monoxide and carbon dioxide in the exit gases were equal, we would get the equation:

$$Fe_2O_3 + 6CO = 2Fe + 3CO + 3CO_2.$$

This equation requires the use of 12·58 cwt. approximately of carbon per ton of pig-iron.

Instances, however, are known of fuel consumption below this figure, and these can only be accounted for on the assumption that a proportion, at any rate, of the ore is reduced directly by carbon in the bosh, according to one or other of the equations:

$$Fe_2O_3 + 3C = 2Fe + 3CO;$$
or, $$FeO + C = Fe + CO.$$

It might therefore be of interest to determine the theoretical possibilities involved in the reduction of pure ore, on the assumption that a proportion of the ore is reduced by CO, and that a proportion is reduced by solid carbon.

It has already been shown that by direct reduction two atoms of iron can be reduced by two atoms of carbon—

* *Op. cit.*, pages 302 *et seq.*

† Journal of the Society of Chemical Industry, 1922, vol. xli, pages 341–347T.

a consumption equivalent to 4·28 units of carbon per 20 units of pig-iron.

Assuming that carbon dioxide and carbon monoxide leave the furnace in equal proportions by volume, then :—

(1) If 20 per cent. of the ore is reduced directly by carbon, the fuel consumption per 20 cwt. of pig-iron will be 11·13 cwt.

(2) If 25 per cent. of the ore is reduced directly, the fuel consumption will be 10·7 cwts. per ton of iron.

(3) If 33⅓ per cent. of the ore is reduced directly, the carbon consumption will be 10 cwt. per ton of iron.

(4) If 50 per cent. of the ore is reduced directly by carbon, the fuel consumption becomes 8·57 cwt. per ton of iron.

The calculated consumption in the last case is lower than anything yet recorded, but no assumption has been made which is contrary to results already reported. Moreover, a carbon consumption of only 10·98 cwt. per ton of pig-iron has already been reported by Bell,* whilst it can readily be shown that the thermal requirements can be satisfied with a pure ore with a consumption of 8·6 cwt. of carbon per ton of iron.

Case (4) can be represented by the following series of equations :—

$$Fe_2O_3 + 2CO = 2FeO + CO + CO_2 + 3{,}840 \text{ calories.}$$
$$Fe_2O_3 + 6CO = 2Fe + 3CO + 3CO_2 + 8{,}520 \text{ calories.}$$
$$2FeO + 2C = 2Fe + 2CO - 73{,}080 \text{ calories.}$$
$$6C + 3CO_2 = 6CO + 174{,}960 \text{ calories.}$$

(N.B.—These reactions are assumed to begin and end at normal temperatures.)

There is a surplus of heat from the above reactions of 114,240 calories. Of this, the heat required for fusing the iron and bringing it to tapping temperature is 72,000 calories. The surplus for other purposes is 42,200 calories. As the ore is pure and very little slag is produced, this is theoretically sufficient to cover the radiation and other losses. Further, the gases leaving the furnace, containing as they do equal volumes of carbon monoxide and carbon dioxide, would have sufficient calorific value to heat the blast, and thus allow of further reductions in the carbon consumption. This, of course, is purely theoretical speculation, but looking back on results previously recorded, it does not appear as far-fetched as it appears at first sight.

In the case of an ore containing a low iron content and giving a high slag yield, a considerable amount of heat is required for purposes which play no part in the chemical reactions. A study of the requirements in this direction shows that the excess fuel for this purpose considerably exceed the fuel required, say, for merely fusing the slag, and raises the question whether the time is not ripe to consider the possibilities of ore treatment prior to use in the furnace for the purpose of reducing the quantity of silicious gangue now associated with it. The matter has already been touched upon by Mr. T. C. Hutchinson and Mr. H. E. Wright in papers to the Institute. If this could be done economically there are possibilities of reducing the fuel consumption, if not to the theoretical limit, yet to a point considerably below that of existing practice.

From whatever standpoint the matter is investigated, it appears probable that a highly active fuel of the type described in this paper opens up far-reaching possibilities in blast-furnace practice. Difficulties may, and probably will, arise in its practical applications, existing furnace designs may have to be altered to meet with the new conditions to the best advantage, factors as yet unforeseen may upset the calculations advanced in these notes ; but, taking everything into consideration, the authors believe that the primary quality of the blast-furnace fuel of the future will be reactivity of such a character and of such a degree as will make it necessary to recast in many respects the previous views of experts with reference to the limits of fuel economy in the smelting of iron.

THE "REACTIVITY" OF COKE.

Addendum by R. V. WHEELER.

The subject of the "reactivity" of coke—that is to say, its power of reacting with oxygen or with carbon dioxide—is one that demands intimate study, with a view to determine the factors upon which the reactivity depends. Apart from this intimate study, however, there is a need for means of obtaining an accurate measure of the reactivity of different samples. It is with this branch of the subject that this note deals. The more complicated research now being carried out in the Fuel Department of Sheffield University, on the factors that determine the reactivity of coke, is still in its early stages, and any discussion of the results so far obtained would be premature.

The method adopted to determine the relative rates of reaction between different solid carbonaceous fuels and (*a*) oxygen and (*b*) carbon dioxide is essentially that used by Rhead and Wheeler in their work on the combustion of carbon† ; the apparatus being a modification of that described by Bone and Wheeler.‡ The apparatus (see Fig. 7) consists essentially of a closed system in which the gas (oxygen or carbon dioxide) is circulated through a column of the coke, which is heated at a known constant temperature in an electric furnace.

The glass globe A serves as a reservoir for the gases. It is connected by a ground joint B with a porcelain tube in which the fuel is packed. A similar ground joint B1 makes connection with a calcium chloride drying tube C, and the head of an automatically acting sprengel mercury pump D, by means of which circulation under atmospheric pressure can be effected. This pump draws the gases from the globe through the tube containing the fuel (the "reaction-tube"), and delivers them under mercury into the wide manometric tube E, whence they return, along the horizontal tube F, to the globe.

A mercury manometer is fixed near the globe and serves for observing the pressure inside the apparatus, and thus following the course of the reaction.

The reaction tube is by-passed by the tube H, a glass spiral being inserted to avoid rigidity, so that when taps L, L′, are closed, and N, N′, open, the gases can be drawn round the apparatus without passing through the fuel. In some experiments it is necessary to obtain samples of the gases in the apparatus at different stages in the reaction. For this purpose the by-passed sampling tubes M can be inserted in the circuit at any convenient point (preferably near the globe, as indicated by the dotted lines in the diagram, a portion of the horizontal tube F being cut away and the sampling arrangement fused in its place). It will be seen that the arrangement of taps on these tubes allows of a sample being shut off without altering the pressure of the gases in the main body of the apparatus, and therefore without interfering with the course of the reaction. Similarly, a by-passed absorption tube R can be introduced elsewhere in the circuit for use when, as during oxidation experiments, it is desired to remove absorbable products of reaction as soon as they are formed.

The reaction tube is 26 cm. long and of 1·2 cm. internal diameter. The fuel, weighing about 2 grammes and sieved through a 10 and on a 30-mesh sieve so as to be of uniform size, is contained within a sleeve of quartz which occupies the middle 9 cm. of the tube only and is kept in position by plugs of a small-bore quartz tubing which just slides into the porcelain tube.

Preliminary experiments with wood charcoal showed that the temperatures at which the reactions proceeded at a convenient rate were (*a*) for oxidation 400 deg. C., and (*b*) for reduction of carbon dioxide 900 deg. C. Oxidation at 400 deg. C. results in the formation mainly of carbon dioxide, a trace only of carbon monoxide being produced ; the progress of this reaction, therefore, can be followed in the apparatus by a fall in pressure of the gas if the carbon dioxide is removed as soon as it is formed. The reduction of carbon dioxide by carbon is accompanied by an increase in volume ; the progress of this reaction can therefore be followed by an increase in the pressure of the gases.

Both reactions can be regarded as unimolecular, and van't Hoff's expression, $1/t \cdot \log \frac{C_o}{C_t} = K$, can be employed for determining the relative rates.

Some of the results obtained are as follows :—

Oxidation at 400 Deg. C.

Sample.	K (*t* = 1 Minute).
A. Wood charcoal	0·000452
B. "Activated" carbon	0·001398
C. Foundry coke	0·000084
D. Gasworks coke	0·000672
E. Sutcliffe, Speakman and Co.'s fuel	0·000414

Reduction of Carbon Dioxide at 900 Deg. C.

Sample.	K (*t* = 1 Minute).
A. Wood charcoal	0·000432.
B. "Activated" carbon	0·000705
C. Foundry coke	0·000049
D. Gasworks coke	0·000158
E. Sutcliffe, Speakman and Co.'s fuel	0·000293

Other series of determinations are in progress with different varieties of coke at different temperatures of experiment. It is probable that a temperature of 450 deg. C. will be found most suitable for routine determinations of the rate of oxidation, and 950 deg. C. for the rate of reaction with carbon dioxide. A works method of determining the rates will be developed from the laboratory method, the apparatus for the latter, though simple enough to use, being rather complicated to instal.

THE CONSTITUTION OF THE ALLOYS OF IRON AND NICKEL.*

By D. HANSON, D.Sc. (the National Physical Laboratory), and J. R. FREEMAN, Junior (the United States Bureau of Standards).

THE research described in the present paper has been undertaken at the National Physical Laboratory, and is a continuation of the investigation carried out by D. Hanson and Hilda E. Hanson,† in which the constitution of the nickel-iron alloys at temperatures below 900 deg. C. was determined. The present authors have extended this work by determining the constitution of the alloys up to their melting points. The only previous investigation of this kind is that of Guertler and Tammann who determined the freezing-point curve. The $\delta \rightarrow \gamma$ transformation, then undiscovered, does not appear in their equilibrium diagram. A further determination of the constitution, using the purest available iron and nickel, therefore appeared necessary.

Preparation of the Alloys.—The alloys were prepared by melting together Armco iron and Mond nickel shot. The composition of the iron was as follows :—

	Per Cent.
Carbon	0·012
Silicon	0·017
Sulphur	0·017
Phosphorus	0·014
Manganese	0·07

The nickel contained 99·98 per cent. nickel. The greatest difficulty in preparing the alloys consisted in keeping them free from carbon. The melts were made in a "carbon-ring" furnace, and, in order to prevent contamination by carbon, it was necessary to enclose the crucible in a refractory muffle. For this purpose, muffles made of a mixture of china clay with 10 per cent. of alumina were used ; the authors are indebted to Mr. V. H. Stott, M.Sc., for the preparation of these muffles. Purified nitrogen was passed into the muffle to prevent oxidation of the melt. Crucibles made from fused alumina were used. The iron and nickel, previously carefully washed clean and free from grease, were melted together in the crucible to form 50-gramme melts. No stirring was required, as it was found that the ingots were quite homogeneous after they had become solid, and drillings taken from top and bottom had the same composition. The analyses of the alloys used are given in Table I.

TABLE I.—*Compositions of Alloys and Arrest Points.*

Reference No.	Composition.	Arrests on Cooling Curve.	
	Nickel per Cent.	Freezing-Point.	Second Arrest.
Pure iron	—	1,530	1,400
FN 1	1·14	1,525	1,444
2	1·98	1,524	1,468
3	2·89	1,518	1,494
4	3·74	1,517	1,501
5	5·09	1,502	—
6	5·80	1,502	—
8	8·02	1,498	—
10	9·96	1,493	—
15	14·6	1,490	—
25	24·7	1,471	—
35	34·8	1,457	—
45	45·1	1,446	—
55	54·6	1,440	—
60	59·3	1,439	1,434
65	65·1	1,436	1,432
67·5	66·7	1,436	—
70	69·3	1,436	1,431
75	74·5	1,437	1,433
80	79·2	1,442	—
85	84·2	1,444	—
90	89·1	1,450	—
Pure nickel	—	1,452	—

Thermal Curves.—The taking of thermal curves of alloys melting at a temperature above 1,500 deg. C. is very difficult, since it is not easy to measure these temperatures with sufficient accuracy. Platinum-rhodium thermocouples can, if suitably supported and protected, be used at these temperatures, but they rapidly deteriorate with use, and must be examined very frequently if reliable results are to be obtained. This deterioration is due to a variety of causes, which cannot now be discussed fully ; contamination by gases, derived from the furnace or melt, is very severe, unless adequate protection is afforded, and failures frequently occurred through cracking of the refractory thermocouple sheath, when the gas from the muffle or furnace rapidly attacked the wire, rendering it brittle. Even when the failure of the sheath did not occur the thermocouple rapidly changed in the neighbourhood of the junction, which was hottest, and temperature readings became unreliable. This was, no doubt, partly due to the fact that the refractory sheath was not completely impervious to injurious gases, but no doubt also due to the elevated temperature alone, since exposure to temperatures over 1,500 deg. C. for any considerable time, even in the absence of foreign injurious gases, is harmful, and produces an alteration in the thermal electromotive force of the element, probably as a result of volatilisation of rhodium. It was found that reliable results were obtained only if the thermocouple was exposed to a very high temperature for a short time ; heating curves could not be obtained in addition to cooling curves, since they involved an exposure of the couple to a high temperature for too long a time, and cooling curves only have been taken.

The apparatus used is illustrated diagrammatically in Fig. 1. The procedure finally adopted was as follows : The metals were melted together in the crucible C, contained in the muffle M, which was inserted in the "carbon-ring" furnace. The muffle was provided with a stopper K, in which were drilled three holes—one (*N*) to lead in the nitrogen gas ; another, covered by a mica cap H, as an inspection window ; and a third, in the centre, through which the thermocouple could be inserted ; this last hole was closed by means of a stopper during the melting of the alloy. After the crucible and metal had been inserted the stopper was luted into the muffle, and the air replaced by nitrogen the muffle was heated slowly until the metal melted, the time taken being approximately 1 hour. The course of this operation could be watched through the mica window, and the moment of complete melting could easily be ascertained. After the metal had been molten about 5 minutes, which was found to be sufficient to secure complete mixing, the thermocouple, encased in a long fireclay sheath, closed at one end, was inserted through the central hole in the lid and lowered into the melt, in which it was placed as near the centre as possible ; this was fairly easily done, since it was possible to see the position of the sheath through the mica window H. The sheath

* "Principles of the Manufacture of Iron and Steel," page 304.

† Transactions of the Chemical Society, 1912, vol. ci, pages 831, 846.

‡ Philosophical Transactions of the Royal Society, 1906, vol. ccvi, A, page 1.

* Paper read at the meeting of the Iron and Steel Institute, on Friday, May 11.

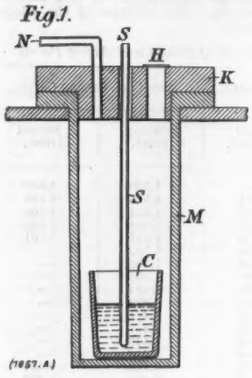
† Hanson and Hanson, "The Constitution of the Iron-Nickel Alloys," ENGINEERING, vol. cx, pages 413, 620 and 655.

and thermocouple were not placed in the melt unless it was ascertained, by reading the temperature of the junction as it was lowered into the furnace, that the temperature was not unnecessarily hot. If this were found to be the case, the sheath was withdrawn and the temperature lowered. As soon as the thermocouple was in place, the current supplying the furnace was reduced, and the cooling curve taken immediately. By this procedure the thermocouple was exposed to an injurious temperature for the minimum time.

Most of the alloys undercooled slightly through their freezing points; in some cases this undercooling was considerable—over 30 deg. C.—and rendered the results unreliable. The difficulty was overcome by inoculating the melt by means of sawdust of iron or nickel for the pure metals, or of a mixture of the two for the alloys. This metallic dust was dropped into the muffle between the thermocouple sheath S and the side of the central hole in the stopper, where a slight gap existed. In this way all undercooling at the liquidus was prevented.

The thermocouple used in the research was calibrated, in the first place, against the standard of the heat division of the National Physical Laboratory, and checked, when

Fig.1.



necessary, by redetermining the melting-point of pure nickel. For the alloys rich in iron, possessing the highest melting points of the series, it was usually necessary to cut 1 in. to 2 in. of wire from the end of the thermocouple after each thermal curve, but for the alloys containing 35 per cent. to 100 per cent. nickel a couple would last for several melts; the maximum number of curves taken with one junction was six, after which it was found to read 2 deg. C. low, and a fresh junction was prepared. The authors have endeavoured to keep errors in temperature measurement, due to couple contamination, less than 2 deg. C., and any junction in which an error greater than this was found has been discarded. Moreover, when the authors' results were plotted in the form of an equilibrium diagram, any point which fell more than 2 deg. C. from the mean curve was redetermined, and was always found to be in error. The freezing-points of some of the alloys have had to be determined several times (in two cases five times each) before agreement could be obtained. If, however, the highest freezing temperature for each alloy is plotted against composition, no point lies more than 2 deg. C. from the mean curve running through them. In some cases, when the thermocouple had become seriously contaminated, the indicated melting-point was 20 deg. C. from this mean curve. It is thought, therefore, that the errors in the equilibrium diagram, due to thermocouple defects, are negligible. An error of 2 deg. C. is not greater than might be obtained from a variety of other causes in experiments of this kind, carried out at such a high temperature.

The results of thermal analysis are given in Table I.

Equilibrium Diagram.—The equilibrium diagram, in the region now investigated, is shown in Fig. 2. This diagram has been plotted from the results of the thermal curves alone, but is confirmed by microscopic examination of the alloys. The portion of the diagram referring to the iron-rich alloys containing 0 per cent. to 10 per cent. of nickel is shown, on a larger scale, in Fig. 3.

Freezing of the alloys begins at temperatures indicated in Fig. 2 by the line A B C D: over the range between A and B, δ iron separates from the liquid; between concentrations represented by the point B and pure nickel (point D) the alloys consist, when just solid, of a continuous series of solid solutions. The freezing-point curve over this range has a minimum at the point C, at a concentration of approximately 65 per cent. to 70 per cent. of nickel. The exact meaning of this minimum in the freezing-point curve will be discussed later.

The iron-rich alloys between the compositions of the points A and B undergo a transformation below the liquidus, at which the δ-iron first formed changes into γ-iron. This transformation is represented by the broken line G E B: the portion G E may be regarded as representing the raising of the δ–γ transformation temperature of pure iron by the addition of nickel. The effect due to nickel is very profound, and an addition of only 3 per cent. raises the transformation point 100 deg. C. The point E represents the point of maximum solubility of nickel in δ-iron, and along the line E B δ-iron of this composition reacts with liquid of the composition represented by B to form γ-iron of the composition represented by F; nickel is more soluble in γ-iron than in δ-iron. It must be pointed out that the position of the point F has not been determined experimentally, and all

Fig.2. IRON-NICKEL ALLOY.

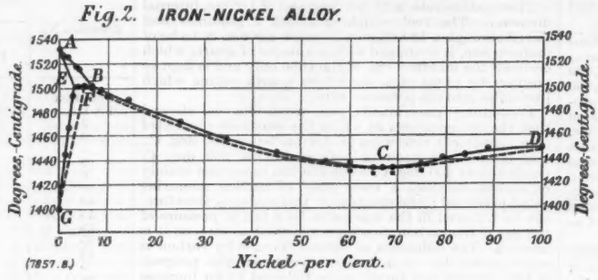


Fig.3. NICKEL-IRON ALLOYS.

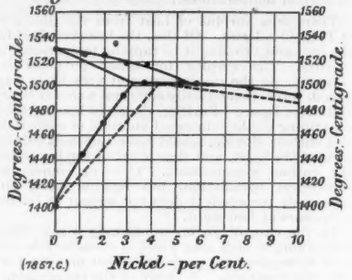


Fig.4.

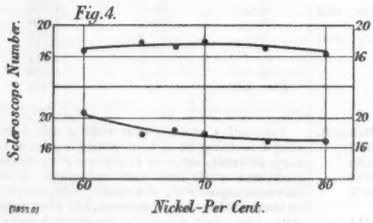


Fig.5

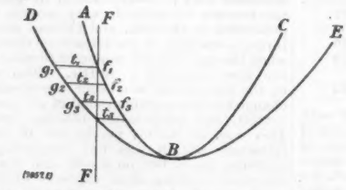
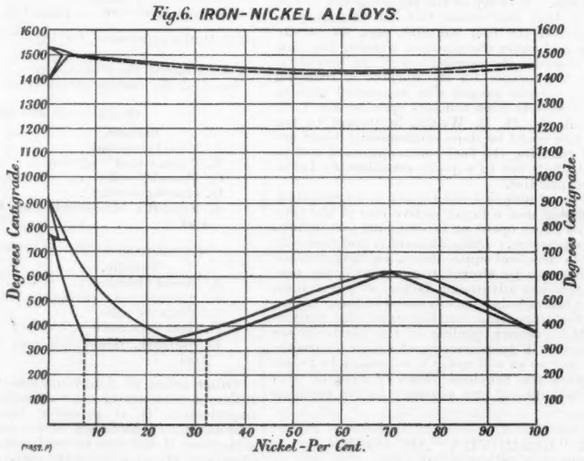


Fig.6. IRON-NICKEL ALLOYS.



that can be said is that it lies somewhere between the points E and B.

The solidus of the system, the line A E F C D, has not been determined by experiment, and is shown dotted. It is, however, very close to the liquidus line, especially over the region between the point B and D; over this range of composition all the alloys have very sharp freezing-points very similar to those of pure substances and it is evident that the temperature range between liquidus and solidus is very small.

TABLE II.

Alloy.	Scleroscope Hardness.	
	As Quenched from 750 Deg. C.	Slowly Cooled to Room Temperature.
FN 60	21·0	17·0
65	18·0	18·0
67·5	18·5	17·5
70	18·0	18·0
75	17·0	17·5
80	17·0	16·5

The exact constitution of the alloy represented by the point C is not very clear. The composition is very close to that of the chemical compound $FeNi_2$, and it might have been supposed that the alloy consists essentially of this chemical compound, particularly as, at a lower temperature, another transformation occurs in the alloys of this system which has a maximum reaction temperature in an alloy of approximately the same composition. In order to obtain some further evidence bearing on this point, a series of hardness tests was made on alloys whose compositions lay on either side of the point C, and the results of those tests are shown in Table II and in Fig. 4. The values given are means of five readings. In no case was the deviation of any reading from the mean value greater than 1.

It is seen that the hardness of the specimens quenched between the upper and lower transformation of the system lies on a continuous curve and shows no discontinuity in the neighbourhood of the composition of the alloy C. The same is found in the case of alloys that have been slowly cooled through the lower transformation point. If the alloy C consisted of the compound $FeNi_2$, either between the melting-point and the lower transformation temperature, or below the lower transformation temperature, it would have been anticipated that a discontinuity, or rather, a minimum, would be found in the hardness composition curve, at the concentration of that compound. It is also of interest to note that the alloy of this composition is relatively soft and ductile and does not possess the great brittleness that is so frequently associated with inter-metallic compounds. In order to settle this question finally, it will probably be necessary to examine other physical properties of the alloys of this series.

The microstructures of the alloys containing 5 per cent. to 100 per cent. of nickel suggest that they have all consisted immediately after solidification of a single constituent. Whether quenched or cooled slowly the alloys possess the simple structure of a single solid solution.

The form of the liquidus curve suggested that the alloys might possibly form two solutions over a short range of composition near 70 per cent. of nickel. The liquidus curve is very flat in this region, and a short eutectic line might easily escape notice. The cooling curves of these alloys were therefore taken with very great care, observations of the rate of cooling being taken every 1 deg. C. instead of every 3 deg. C., which was the interval usually adopted. In the alloys containing 60 per cent., 65 per cent., 70 per cent. and 75 per cent. nickel a small second arrest point was observed at a temperature of 1,432 deg. to 1,434 deg. C., and this arrest point is indicated on Fig. 2. In each case a slight recalescence, about half of 1 deg. Centigrade, was noticed, so that the observed temperatures are a little lower than the "equilibrium" transformation points. In no case, however, is this small second arrest point more than 5 deg. C. below the liquidus. The cooling curve of the alloy containing 67·5 per cent. of nickel gave a very slight indication of a second "arrest" at a rather lower temperature (1,428 deg. C.), but this was much smaller than that found in the case of the other alloys, and was too indefinite to be considered a definite "arrest" point.

The occurrence of a second arrest of this kind may indicate the presence of a eutectic, stable or metastable, or may merely be due to cooling too rapidly for equilibrium, in regard to chemical composition to be maintained during the process of solidification. In the present instance the very small character of the arrest point in all the alloys in which it is found suggests that the latter explanation is the correct one, and that the alloys consist entirely of solid solutions and are not eutectiferous, even if cooled relatively rapidly. The absence of a second arrest in the alloy containing 67·5 per cent. of nickel suggests

that this alloy lies very close to the minimum of the freezing-point curve. The occurrence of a second arrest point on either side of this minimum would be expected if the rate of cooling were not slow, as a result of the normal process of freezing in such a case. Fig. 5 illustrates this. The curves A B C and D B E represent respectively the liquidus and solidus of such a system, which consists of a continuous series of solid solutions whose freezing-point curve falls to a minimum at B. An alloy F, near this minimum, begins to freeze at the temperature t_1, by depositing crystals of composition g_1. If equilibrium between the solid and liquid phases is maintained by slow cooling, the compositions of the phases are represented at the temperatures t_2, t_3 by g_2, g_3 for the solid, and f_2, f_3, for the liquid phase, while at t_4 the whole alloy is just solid and has the uniform composition F. If, however, the rate of cooling is not very slow, "cored" crystals are formed, and the freezing range of the alloy is extended, and the temperature of the minimum point may be reached before solidification is complete, at which temperature the composition of the remaining liquid is represented by B. If, when this temperature is reached, an appreciable quantity of liquid alloy remains unfrozen, as is manifestly possible with rapid rates of cooling, an arrest point must occur, since liquid of this composition has a definite freezing-point, the solid and liquid phases having the same composition. In taking a cooling curve the rate of cooling is seldom, if ever, sufficiently slow to prevent "coring" of the solid solution, and the conditions are therefore favourable for the production of spurious arrest points of the kind indicated.

In order to verify further the above conclusions, an alloy containing 65 per cent. of nickel was re-melted, allowed to solidify at a moderate rate (about cooling curve rate), and quenched from a few degrees below its solidification point. If the system were eutectiferous, it was anticipated that two phases would be present in the alloy after this treatment; if the system was one consisting, when in equilibrium, of only one phase, two phases could not be formed under any conditions of rapid cooling. Microscopic examination showed that the quenched sample consisted of one solid solution, and indicated that the metal was of the type illustrated in micrograph Fig. 7.

Delta Iron.—An attempt was made to show, by means of the microscope, that δ-iron, and the δ-iron phase, differed from the γ-iron phase, and that the change from one to the other was accompanied by a recrystallisation of the material. The transformations in iron and iron-nickel alloys take place with such rapidity on cooling, that it is impossible to preserve, by quenching, the δ and γ modifications. Attempts were therefore made to preserve the structures existing at high temperatures by the "vacuum etching" of polished surfaces, previously prepared. Specimens of iron were polished and heated in a porcelain tube to temperatures above and below the δ-γ transformation point, but no clear indications were obtained of the structures that existed at the high temperature. The surface markings on the specimens after this treatment were very complex; iron that had been heated above the δ-transformation point appeared to possess indications of a structure that was not found if this temperature was not exceeded, but the complexity of the markings made any definite conclusions impossible. Pure iron appeared unlikely to give conclusive evidence, and an alloy containing 1 per cent. of nickel was tried, with more promising results. Etching in a vacuum was discarded, on account of the difficulty of obtaining a tube that was completely impervious to gas at the high temperatures, and finally narrow tubes of silica, containing an atmosphere of pure nitrogen, were used. A polished specimen of alloy was placed in each of two tubes, which were filled with nitrogen at a pressure of 20 mm., sealed, and inserted in a furnace at a temperature of 1,300 deg. C.: they were maintained at that temperature, which was in the γ range, for 2 hours, at the end of which one was removed and cooled quickly. The other was raised rapidly to 1,450 deg. C. (within the δ range) in 14 minutes and similarly cooled. The specimens were removed from their tubes and examined, when a striking difference between the two was found. The appearance of the specimen heated for 2 hours at 1,300 deg. C. is shown in micrograph Fig. 7, at a magnification of 50 diameters. It indicates a system of polygonal crystals, which may be assumed to represent the γ-iron that existed at the annealing temperature. The appearance of the other sample that had been similarly heated to 1,300 deg. C. for 2 hours, but had finally been raised to 1,450 deg. C. in 14 minutes before cooling is shown in micrograph Fig. 8, also at a magnification of 50 diameters. A system of well-defined crystals, of larger size than those shown in Fig. 7, is indicated, together with a confused mass of markings, on a smaller scale, that appear to represent previous systems of crystals. While it is thought that the well-defined large crystals represent the structure of the δ-phase that existed when the alloy was removed from the furnace, and the ill-defined smaller crystals the γ-phase that existed previously to the formation of δ-iron, this is not conclusively proved by these observations, since it may be argued that the large crystals of Fig. 8 are γ-iron crystals that have grown larger as a result of heating to a higher temperature. Examination under a higher magnification, however, indicates other differences. In the sample heated for 2 hours at 1,300 deg. C. the "crystals" are found to be crossed by a system of markings, probably formed as a result of the volume change at A3 on cooling. It was observed that these markings were approximately parallel in any one crystal, but that they did not cross a crystal boundary, as is shown in micrograph, Fig. 9, at a magnification of 150 diameters. In the other sample similar markings were found, but they appeared, as a rule, to be unrelated to the boundaries of the coarse "crystals," or to those of the smaller but less distinct crystals already mentioned. These features are shown in the micrograph, Fig. 10. The well-defined black boundaries represent the crystals that existed when the specimen was removed from the furnace, while the less distinct, shadowy "boundaries" mentioned above are also visible (they are best seen if the photograph is held some distance from the eye). The surface markings, which suggest wrinkles, are clearly visible, and they appear to be quite unrelated to these systems of boundaries. The presence of markings of this kind, not related to the coarse crystal

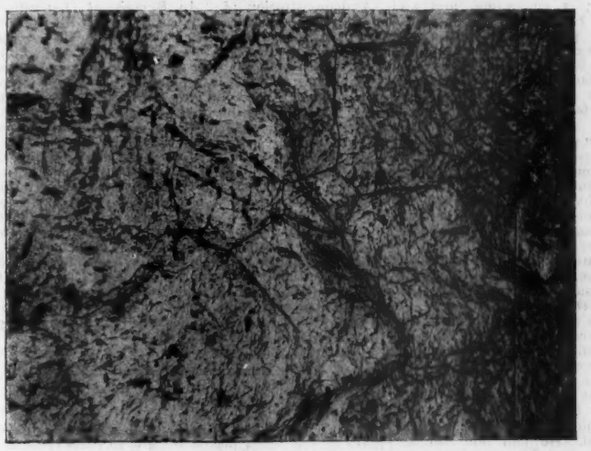


FIG. 7. 1 PER CENT. NICKEL IRON, HEATED FOR 2 HOURS AT 1,300 DEG. C. IN NITROGEN AND COOLED QUICKLY. HEAT ETCHED. × 50.

FIG. 8. 1 PER CENT. NICKEL IRON, HEATED FOR 2 HOURS AT 1,300 DEG. C., RAISED TO 1,450 DEG. C. DURING 14 MINUTES AND COOLED QUICKLY. HEAT ETCHED. × 50.

FIG. 9. SAME AS FIG. 7, SHOWING SURFACE MARKINGS THAT APPEAR TO CHANGE DIRECTION AT CRYSTAL BOUNDARIES. × 150.

FIG. 10. SAME AS FIG. 8, SHOWING SURFACE MARKINGS UNRELATED TO CRYSTAL BOUNDARIES. × 150.

grains, is explained by assuming that these crystals were δ-iron, which have changed into a completely new system of γ-iron crystals during cooling, and that the markings are due to the $\gamma \rightarrow \alpha$ change, in which the newly formed crystals of γ-iron only could take part. These observations indicate a change in the crystal structure at the $\delta \rightarrow \gamma$ transformation temperature. They confirm Dr. A. Westgren's conclusion,* based on X-ray analysis, that δ-iron and γ-iron are constitutionally different.

Complete Constitutional Diagram of Nickel-Iron Alloys.—If the results obtained in this paper be combined with those given in the paper by D. Hanson and H. E. Hanson, in which the constitution of the alloys at lower temperatures is described, it is possible to construct the complete equilibrium diagram for the iron-nickel system. This is given in Fig. 6.

PHYSICAL SOCIETY OF LONDON.

AT the meeting held on April 27, 1923, at the Imperial College of Science, Mr. Alexander Russell, M.A., D.Sc., in the chair, a paper on "*The Analysis of Bubbles in Glass*," by the research staff of the General Electric Company, Limited, London (work conducted by Mr. J. W. Ryde and Mr. R. Huddart), was read by Mr. Ryde. In order to distinguish bubbles generated by chemical action in glass from those introduced by mechanical processes spectroscopic tests are made for the presence of nitrogen. In order to liberate the gas from the bubbles a specimen of the glass was placed in one limb of a quartz U-tube and mercury in the other, and the glass was heated and then disintegrated by sudden cooling, the tube being plunged into cold water at the same time that the mercury was thrown on to the glass.

In the discussion which followed Mr. J. Guild expressed surprise that the spectrum of nitrogen should be distinguishable in the presence of mercury vapour, which might be expected to carry most of the discharge and to mask the effect of the nitrogen.

Dr. E. A. Owen inquired what precautions were taken to prevent atmospheric gases from entering the tube along with the mercury.

Dr. R. T. Beatty suggested that if the method could be made quantitative it might be used to find out what becomes of the gas which disappears from the interior of a discharge tube during the life of the latter.

Mr. J. W. Ryde, in reply to the discussion, said that the nitrogen spectrum would be completely masked by that of mercury if the tube were warm, and would be only just distinguishable at ordinary temperatures. In practice, therefore, one limb of the tube is immersed in liquid air whereby satisfactory results can be obtained. In filling the tube with mercury every precaution is taken, by drying and boiling the mercury and so on, to prevent the admission of gaseous impurities. Greater difficulty is experienced, however, in getting rid of the gases adsorbed on the silica walls of the tube, which have to be heated repeatedly with a blow pipe. The method does not readily lend itself to quantitative applications, as the line intensities are much affected by the fact that the discharge takes place in a mixture of gases.

A paper on "*A Simple Regenerative Vacuum Device and Some of its Applications*" was read by Dr. H. P. Waran, M.A., Ph.D.(Cantab.), F.Inst.P. The paper dealt with the difficulties arising from residual traces of air fouling the vacuum above the mercury column in syphon gauges and other devices. A remedy was suggested in the form of a small attachment taking the shape of a bent capillary tube ending in a bulb. This enabled the air to be repeatedly pushed into the vacuum of this bulb, the mercury at the bottom of the capillary preventing the subsequent return of the air. With such an arrangement fitted to the top of a syphon gauge the height of the column of mercury becomes a true measure of the gas pressure, subject only to the definite correction for the vapour pressure of mercury and temperature. The device was regenerative in the sense that, irrespective of any progressive fouling of the vacuum, a fresh-air-free vacuum was automatically created by it every time it was brought into action. As typical examples of the wide field of utility of the device its application to mercury barometers and to mercury vapour lamps was also briefly discussed.

Dr. R. T. Beatty, in the course of the discussion, said that the device was a remarkably simple and effective one. If it could be put on the market in combination with an oil trap and a drying tube it would fill a long-felt want.

Dr. G. B. Bryan said that if the capillary tube were too small there might be difficulty in getting the mercury to move air bubbles along it, as there is a tendency for the mercury to slip past a bubble. He inquired as to the kind of glass employed.

Dr. E. A. Owen mentioned a somewhat similar device which has been in use for some time at the National Physical Laboratory.

Mr. F. A. Gould (communicated): The author has drawn attention to a device which has been known for many years to users of precision barometers. In the "Travaux et Memoires du Bureau International," Tome II (published in 1883), there is a description of a barometer in which practically the same device is used. It is recorded there that the object of the device was not entirely fulfilled to the satisfaction of the Bureau International, as it was found that "the complete expulsion of the air from the vacuum space of the barometer required the passage of a considerable quantity of mercury upwards through the instrument, a procedure which probably introduced fresh small bubbles of air from the lower end of the barometer." The device for renovating the vacuum has also been used in this country. A reference standard mercury barometer incorporating this design was constructed by Dr. Aston, formerly of the Royal Aircraft Factory, Farnborough, during the war, and is still in use at Kidbrooke, while a similar principle was adopted in an experimental standard barometer which, though designed at the National Physical Laboratory in 1913, was not filled until 1922. The efficiency of the device has not yet been tested at the National Physical Laboratory. The reference made by the author to the possibility of securing an accuracy of 0·001 mm. of mercury in the use of a syphon gauge requires some qualification. It is well known that the capillary action of mercury is not negligible, even in tubes of comparatively large diameter, *e.g.*, 1 in. Exact equality in the amount of the capillary depression in each limb of the gauge cannot be relied upon, and it would be necessary to select a syphon tube of internal diameter at least 1·3 in. in order that the differential capillary error should not exceed 0·001 mm. Other causes would render this degree of accuracy difficult to secure. The reference to the meteorological barometer is misleading, and an estimate of 0·1 mm. would be far nearer the truth than 0·01 mm. for all ordinary purposes. It is usual to insert an air trap in the tubes of all Kew-pattern barometers (*i.e.*, those barometers with uniform, contracted scales and no fiducial point), but it is doubtful whether it would be practicable to fit the "vacuum-renewal" device to the ordinary portable types of mercury barometers.

Mr. J. Guild said that he was particularly interested in the application to mercury lamps and would like to know more of the author's experiences in this connection. The models shown were on a small scale and suitable for low voltages, but where a bright discharge is exacted the vapour pressure of the mercury becomes considerable and it might be expected that in these circumstances the mercury seal would cease to be effective.

Dr. D. Owen asked if the author could furnish some experimental results. Had he, for instance, data of inter-comparison of two syphon barometers constructed as described and subjected to the same conditions?

The author, in reply to the discussion, said that the device could very readily be combined with an oil trap and drying tube. Various difficulties have to be overcome in practice, but there is none in getting the mercury to move the bubbles provided a capillary tube of 0·5 mm. diameter be used. It was not surprising that the idea should have occurred to others, but he was not previously aware of the fact and had thought that other workers might find the device useful. He had not had an opportunity to obtain experimental data, but he hardly thought a syphon barometer would be capable of a total accuracy of 1 μ. That figure represented the maximum error due to imperfection of the vacuum. The device would not be effective for an indefinite period, but might increase the life of a barometer by some years. The mercury lamps of which he had had experience were some taking 2 amperes at 110 volts which he had made for laboratory use. In such lamps when hot the mercury rises about 1 cm. The construction of the apparatus is such that there is no tendency for the rise in vapour pressure to break the mercury seal.

In regard to the previous work on the subject in France, he concluded from his own inquiries that this had produced but little impression here, and he trusted his paper would serve to advance the matter.

A paper on the "*Application of the Eötvös Torsion Balance to the Investigation of Local Gravitational Fields*," by Captain H. Shaw and Mr. E. Lancaster-Jones, B.Sc., was read by Captain Shaw. In a paper read before this society on February 9 the Eötvös torsion balance was described in detail, and the theory of its operation considered. The preparation of suitable torsion wires was mentioned, but no practical tests with the instrument were discussed. In view of the sensitivity of the balance, which, as previously stated, measured derivatives of gravity of the order of 10^{-9} C.G.S. units, it was anticipated that a gravitational survey of the laboratory would disclose the varying effects of the neighbouring masses of the walls, pillars, &c. The balance was therefore set up at different stations in the laboratory, and the derivatives at each station measured. The measurements at several stations were checked by repetition, and the results compared with the theoretical values. The mutual consistency of the results obtained at each station and their general agreement with the calculated effects exceeded expectations, as the local gravitational field varied so rapidly that the theoretical assumption of a uniformly varying field in the neighbourhood of a station was obviously vitiated.

Dr. Alexander Russell said that the authors' previous paper on the Eötvös balance had excited considerable interest amongst scientists. The sensibility of the instrument was wonderful and the agreement between theoretical expectations and practical measurements extremely satisfactory.

Mr. E. Lancaster-Jones said that the calculations were based on the assumption that third order derivatives of the gravitational potential could be neglected, but in the experiments described this condition was by no means fulfilled. The close agreement between theoretical and practical results was all the more surprising in view of this fact.

A demonstration of "*An Electromagnetic Inductor*" was given by Mr. L. F. Richardson, F.Inst.P. The apparatus shown is intended for teaching purposes, and serves to introduce students at an earlier stage than usual to a quantitative conception of electromagnetic E.M.F. Like the Lorentz apparatus, the present instrument involves a rotating conductor and produces a steady electromotive force. Two bicycle wheels are mounted vertically and co-axially, and are driven in opposite directions by a 4-volt motor, the driving band being constituted by an endless wire (stranded picture wire was used), which passes from the motor pulley over one wheel, under an idle pulley, and back over the other wheel to the motor pulley. The electromotive forces generated by the revolution of the wheels in the earth's field are thus added (the rims of the wheels being electrically connected through the driving wire), and their sum can be tapped from terminals connected to the hubs of the wheels. The speed of the wheels is found by counting the revolutions against a stop watch, one of the spokes being marked for this purpose, and from this speed and the length of a spoke the E.M.F. can be found in terms of H. It can be compared with that of a Daniell's cell by arranging the latter as the source of current in a potentiometer. The cell is connected in series with a fixed resistance of 100,000 ohms, and with a variable resistance of ohms and tenths, the inductor in series with a galvanometer being shunted across the variable resistance. Results accurate to 4 per cent. can be obtained with care. Errors due to thermal E.M.F. are eliminated by turning the apparatus through 180 deg. and repeating the observations.

A demonstration of "*An Experiment Demonstrating Time-Lag in Vision*" was given by Dr. F. Ll. Hopwood, D.Sc., A.R.C.Sc., F.Inst.P. The experiment* depends upon the fact that the time lag in visual perception is greater for dimly than for brightly-illuminated objects. A pendulum swinging in a plane carries a glow lamp at its lower end. A second glow lamp is fixed immediately below the mid position of the swinging lamp, and both are viewed with one eye in the ordinary way, while in front of the other eye a metal disc perforated at its centre is so placed as to cut off most of the light reaching that eye. The pendulum then appears to be a conical instead of a plane pendulum, the apparent direction of rotation changing when the disc is transferred from one eye to the other. This phenomenon is explained by the fact that the image seen by the obstructed eye corresponds to an earlier position of the swinging lamp than does the image seen by the free eye, in consequence of the greater time-lag in the former case. The images seen by the two eyes thus fail to coincide, and as they are combined by the binocular process into a single object this object appears to be in front of, or behind, its true position according to the direction of swing and to whether the right or left eye is obstructed.

CATALOGUES.

Plastic Wood.—A further pamphlet of practical notes on the use of plastic wood is to hand from Necoll Industrial Collodions, Limited, Windsor House, Victoria-street, London, S.W.

Surveying Instruments.—A useful descriptive summary of recent improvements in British-made surveying instruments, which is a reprint of a paper by Mr. W. H. Connell, has been issued by Messrs. Cook, Troughton and Simms, Limited, York.

Steelwork.—A new edition of their priced list of wire fencing, railing, staircases, sashes, ventilators, roof principals and complete buildings, has been received from Messrs. David Rowell and Co., Limited, 14, Howick-place, Westminster, London, S.W.

Heating Fittings.—A list of copper and brass tubes, injectors, heater batteries, radiators, steam valves, separators, and similar heating fittings is to hand from Messrs. Fryer and Co., Rouen, France. Most of these fittings are made to the patents or designs of Messrs. Royle, Limited, Manchester.

Concrete Machinery.—A little booklet illustrating machines for stone crushing, clinker-crushing, concrete mixing, moulding slabs and roofing tiles, stone drying and tarring, and a conveyor mounted on two wheels, has been received from Messrs. Winget, Limited, Grosvenor Gardens, London, S.W. 1.

Electric Trucks.—A large card illustrating electric runabout cranes and trucks for yard or workshop service is to hand from Messrs. Ransomes, Sims and Jeffries, Limited, Ipswich. The cranes are made in three capacities for loads up to 1 ton, the trucks being suitable for carrying or hauling loads of 26 cwt. and 2 tons.

Steam Engines.—Tables of dimensions, powers and prices of a series of enclosed vertical steam engines, with forced lubrication are given in a catalogue received from Messrs. Dickinson and Burne, Limited, Arbroath (recently removed from Guildford, Surrey). The engines are made in single, compound and triple-expansion types and range in size from 4 b.h.p. to 670 b.h.p. The parts are fully standardised.

Sewage Pumps.—Messrs. Gwynnes Engineering Company, Limited, Hammersmith, London, W., have sent us a catalogue of the Gwynne-Pennell rotary trap for use in pumping liquids containing hard or fibrous solid matter. The effect of the trap is to allow the water to pass to the pump and reject the solid matter, and it is used as an auxiliary to enable an electrically-driven centrifugal pump to be employed where it would not otherwise be practicable.

Power Transmission.—A neatly bound catalogue of over 300 octavo pages dealing specially with mechanical means of transmitting power has been issued by Messrs. Frank Wigglesworth and Co., Limited, Shipley, Yorks. The principal items are shafting, couplings, bearings, pulleys, tooth gears and friction clutches, but all the related parts and accessories are included. Full particulars of form and dimensions and methods of fixing are given by text and illustrations in a manner suitable for the millwright, and prices are also stated. Much useful technical data is given, and the whole method of compiling the catalogue is to be commended.

* ENGINEERING, vol. cxiii, pages 626 and 630.

* C. Pulfrich, Die Naturwissenschaften, Heft 25–27 und 33–38, 1922.